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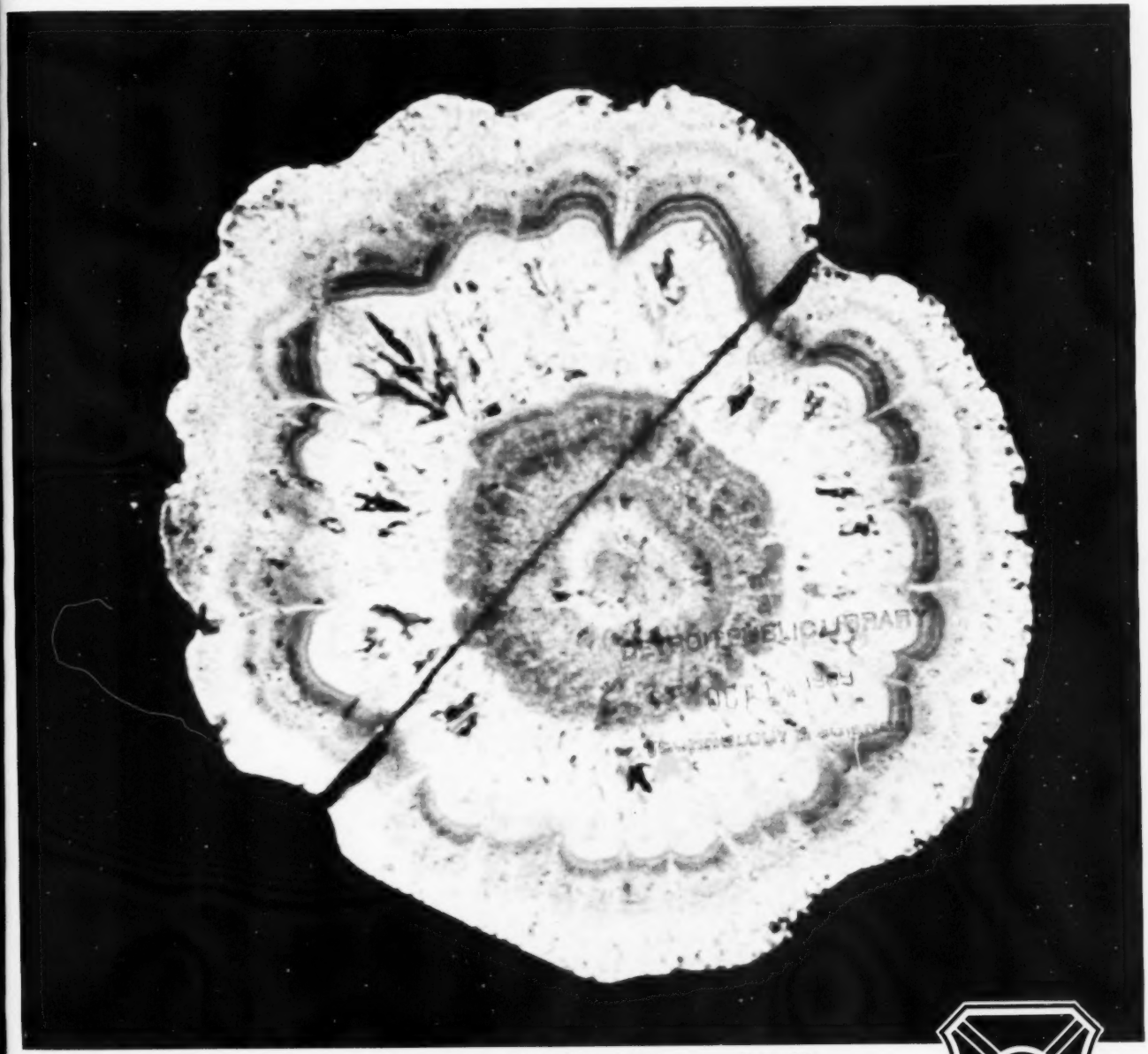
OAR RESEARCH REVIEW

OFFICE OF AEROSPACE RESEARCH ★ UNITED STATES AIR FORCE



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OAR RESEARCH REVIEW

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DEVELOPMENT OF A THEORY OF SOLAR FLARES	1	Dr. Peter A. Sturrock, Stanford University
EXISTENCE AND BEHAVIOR OF SIMILAR SOLUTIONS OF BOUNDARY-LAYER PROBLEMS	5	Major Wm. R. Trott, AFOSR
DAYGLOW PROFILE	6	Aeronomy Laboratory, AFCRL
HYDROGEN GAS GENERATOR FOR FIELD USE	7	Aerospace Instrumentation Laboratory, AFCRL
HOW HAILSTONES GROW	8	Meteorology Laboratory, AFCRL
PRESSURE SURFACES AND SST PASSENGER DISCOMFORT	10	Aerospace Instrumentation Laboratory, AFCRL
RECENT HIGH-SPEED GAS-DYNAMIC RESEARCH AT THE VON KARMAN INSTITUTE FOR FLUID DYNAMICS	11	Major Richard T. Boverie, EOAR
THE ORDERING OF THE SOLAR SYSTEM	13	Space Physics Laboratory, AFCRL
AN EXPLANATION OF GRAVITY	14	Space Physics Laboratory, AFCRL
FORECASTING THE MAGNITUDE AND DURATION OF POLAR-CAP ABSORPTION	16	Ionospheric Physics Laboratory, AFCRL
THE MEN BEHIND THE MACHINES: A SURVEY OF INFORMATION–PROCESSING PERSONNEL	17	Rowena W. Swanson, AFOSR
A NEW APPROACH TO MONITORING NERVOUS-SYSTEM FUNCTIONAL STATE AND PERFORMANCE	21	Dr. H. J. Sander, AFOSR
PRECISE LONG-RANGE FORECAST OF SATELLITE DECAY	22	Eunice C. Cronin, AFCRL
MATHEMATICAL MODEL FOR BLOOD-SUGAR REGULATION OF THE HUMAN BODY	24	Dr. Lynn E. Wolaver, ARL
VAPOR PRESSURE OF RARE-EARTH ELEMENTS	25	Capt James M. McCormack and Lt Col Richard K. Saxer, FJSRL
SLEEP AND COMPUTER PROGRAMMING	26	Data Sciences Laboratory, AFCRL
THE RELEVANCE OF BASIC POLYMER RESEARCH TO THE AIR FORCE	27	Dr. William L. Ruigh, AFOSR

ON THE COVER

The cover photo shows the cross section of a hailstone, in complete outline.

When a hailstone is sliced through the middle and photographed with a polarized filter, AFCRL researchers can readily see its structure and can learn something of its growth pattern. This cover photo, for example, shows several onion-like layers which tell the AFCRL investigators that the hailstone in question has ascended and descended several times through a cloud layer during which actions moisture formed around the hailstone and froze.

The dark spots on the photo represent small bits of already formed ice that accreted to the hailstone during its descent through the cloud layer.

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JACOB SEIDEN *Editor*

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DEVELOPMENT OF A THEORY OF SOLAR FLARES

DR. PETER A. STURROCK, Institute for Plasma Research, Stanford University

The "solar-flare" phenomenon is of interest for several reasons: (1) it involves intriguing problems of observation, data reduction, and theoretical analysis; (2) a solar flare causes many significant terrestrial effects such as magnetic storms, aurorae, and sudden enhancement of atmospherics; (3) the flux of high-energy particles produced by an intense flare presents a significant radiation hazard to astronauts; (4) many solar phenomena, such as radio bursts, are by-products of a solar flare; (5) other astronomical objects–for example, some galaxies–have outbursts that appear to be similar to solar flares.

Astronomers define a solar flare as a sudden brightening of a portion of the sun as seen in the Hα line of hydrogen. Many observatories all over the world maintain regular "patrols" of the sun, taking Hα photographs two or three times each minute. We now know that flares can be recognized also by X-ray emission and by EUV radiation. Occasionally, a flare may be seen in white light. Flares also result in several types of radio emission, in the production of high-energy particles, and in the ejection of clouds of plasma which, on arrival at earth, produce geomagnetic storms.

In trying to understand a phenomenon as complex as a solar flare, the crucial step is to determine the key ingredient and key process involved. A flare may or may not produce a Type-II radio burst, and it may or may not produce a geomagnetic storm; thus these and other properties are secondary and not essential. Since Type-III radio bursts are sometimes produced when no flare is observed, one may also speculate that appreciable brightening in Hα is not an essential property of a flare. In case it appears that the production of a Type-III burst is an essential property, it should be added that many flares do not produce Type-III bursts.

Although, as we have remarked, a flare is "defined" as being a "sudden brightening in Hα," this observational definition does not seem appropriate as a basis for theoretical study.

While it is not possible to specify any unique consequence of a flare as defining a flare, there is a circumstance in the occurrence of a flare which does seem to be reliable. Flares occur in regions of strong magnetic field. Furthermore, flares seem to be related to field reversal; for instance, the first bright points of a flare normally lie close to the "neutral line" which separates a region of north magnetic polarity from a region of south magnetic polarity. Furthermore, if a flare occurs in a region which appears to be unipolar, it usually develops that there was a small

inclusion of opposite magnetic polarity at the place where the flare occurred.

The close association between flares and magnetic field has been recognized for a long time. It has also been recognized that a flare is a phenomenon that involves only the *atmosphere* of the sun, namely, the regions known as the chromosphere and corona. Although occasionally a flare may be seen in white light, and even though sometimes there is evidence of a change in the magnetic field at the photosphere, there is no direct evidence that a flare necessarily involves activity at the photosphere; and there is substantial indirect evidence that it does not.

Flares occur with a wide range of "Importance": an Importance-3 flare is estimated to release 10^{32} ergs, and the build-up of the flare takes only a few minutes. Hence a flare is some kind of explosion—that is, a sudden and apparently spontaneous conversion of energy from one form to another. Since the phenomenon occurs in the atmosphere of the sun, the energy which is released must have been stored above the photosphere. It has been recognized for a long time that the only ingredient of the sun's atmosphere which could provide the necessary energy is the magnetic field. This assumption is of course fully confirmed by the fact that flares occur only in regions of strong magnetic fields. The debate among theoreticians which has been going on for many years has centered on the following key questions: (1) what is the magnetic-field configuration which makes a flare possible? (2) how was the energy in this configuration built up, and what was the source of the energy? (3) what is the mechanism for the sudden release of this energy? and (4) how does this sudden release lead to the observed properties of the solar flares?

One can use simple physical arguments to make a strong statement concerning question 1: *the magnetic-field pattern which is in existence before a flare must involve currents.* The reason for this is that, since the normal component of magnetic field at the photosphere is fixed (due to the high conductivity and inertia of this layer), a current-free field configuration is the minimum-energy configuration consistent with this boundary condition. There is "free" or "available" energy only if there are currents in the chromosphere and corona. On the other hand, the density in the atmosphere is so low that forces such as pressure gradient will be small compared with the Lorentz force j x B. This has led to the view that, in the preflare state, j x B is virtually zero, so that the field approximates a "force-free" field. Two of the more specific flare theories, those of Sweet, (1) and of Gold and Hoyle, (2) are based on this assumption. With this answer to question 1, the obvious answer to question 2 is that the magnetic-field configuration has been built up by movement of the photosphere, which carries magnetic-field lines with it, so that the source of flare energy is the kinetic energy of photospheric motion.

This category of flare theory suffers from the following objections: (1) *a force-free field configuration involves only closed magnetic-field lines.* But flares often produce Type-III radio bursts at the very beginning of the flare. These are produced by streams of high-energy electrons which travel radially outward from the sun, and must travel along magnetic-field lines. Hence this phenomenon argues that the preflare magnetic-field configuration has *open* field lines, thus conflicting with all models involving only closed field lines. (2) *Flares sometimes repeat faithfully and periodically, to form a sequence of "homologous" flares, with no discernible changes at the photosphere.* This implies that the preflare state, once it is destroyed, may be reconstructed without photospheric motion. This fact contradicts the assumption that flare energy is derived from photospheric motion.

It should be mentioned that a theory of solar flares advanced by the author in collaboration with Professor Bruno Coppi (3) involves a closed-field configuration, and so is open to the first objection raised above, although it is not open to the second objection. (This is related to the fact that the energy in that model is not purely magnetic.)

In the course of the last three years, we have been working at Stanford on a theory of solar flares (4) which seems to offer reasonable answers to the four questions listed above, and which appears to be free from the objections to which earlier theories are prone. This model is based on the knowledge that a substantial fraction of the magnetic-field lines originating at the polar photosphere are open field lines, penetrating far into interplanetary space. The basic reason for this assertion is that the contrary assumption, that all magnetic-field lines close within the near neighborhood of the sun, is incompatible with the existence of the solar wind.

When one now considers the topology of magnetic-field lines above a simple bipolar active region, taking the above fact into account, one is led to the interesting field configuration shown in Figure 1. A certain fraction of the magnetic flux linking the two regions of opposite polarity will be linked by closed magnetic-field lines. However, another fraction will be associated with open magnetic-field

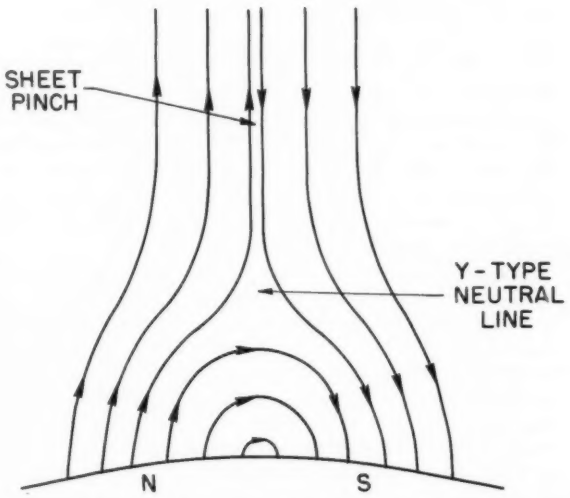

Figure 1. Schematic representation of magnetic-field pattern above a bipolar magnetic region, showing the transition from closed-field lines at low heights to open-field lines at great heights, involving the Y-type neutral line and sheet pinch.

lines. It is this second group of magnetic-field lines which provides a channel for the escaping coronal gas which constitutes the solar wind.

An important property of this field configuration is that the boundary between the two open flux tubes must carry a sheet current, since there is a sharp reversal in field direction at that surface. Hence, this field configuration incorporates free energy which can be released without changing the connection of magnetic-field lines at the photosphere. Since this field pattern contains open field lines, there is no difficulty in understanding the fact that Type-III radio bursts may be caused at the very beginning of a flare by streams of electrons traveling radially outward from the sun.

We may now consider the second question, that of the build-up of this configuration and of the energy supply. The existence of the corona is due to the fact that the photosphere generates high-intensity sound waves which travel through the chromosphere and into the corona. The sound waves are dissipated by one or more processes, and it is this dissipation of energy which heats the chromosphere and the corona to temperatures far above the temperature of the photosphere.

This energy supply also makes available the energy necessary to drive the solar wind. This means that the acoustic energy flux which propagates along the closed-field lines is used entirely in heating the corona; by contrast, the acoustic energy flux which travels along the open-field lines goes partly into heating the corona and partly into driving the solar wind. In consequence, the density and temperature in the closed-field regions should be higher than the corresponding values at the same height in the open-field region. Hence, in the region of the "Y-type neutral line" shown in Figure 1, the pressure is higher just inside the cusp (the region of closed-field lines) than just outside the cusp (the region of open-field lines). The result of this pressure difference should be that closed-field lines are driven into the sheet-like aperture between the two open flux tubes. This expulsion of field lines provides a mechanism for progressively enlarging the fraction of magnetic flux which is associated with the open-field region. Hence, it is a way of building up the free energy of this configuration. We now see that the free energy of this field configuration may be derived from the nonthermal energy flux which is responsible for heating the corona.

We may at this point pause to see whether the above ideas satisfy numerical checks. As we have noted, a large flare releases 10^{32} ergs. It also covers an area of about 10^{20} cm^2. This indicates that the scale height of the open-field configuration will be of the order of 10^{10} cm. Hence, the energy associated with the open-field region can make available the required stored energy provided that the field strength at a height of 10^{10} cm is of the order of 50 gauss. This seems entirely reasonable, since the surface field of a plage region is in the range of 50-100 gauss.

We may also consider the energy supply. The fact that the flares sometimes repeat in homologous sequences gives us an estimate of the time it takes to restore the energy released at the time of a flare. The time interval between recurring Importance-3 flares is about one day, or 10^5 sec. Hence, we see that the required energy flux is 10^7 ergs cm^{-2} sec^{-1}. According to Osterbrock, (5) the acoustic energy flux over the normal photosphere is 10^7 ergs cm^{-2} sec^{-1}, but may be higher by a factor of 10 in active regions. Thus it seems that the proposed source of energy is adequate to meet the needs of this model.

We may now turn to the third question—that of the mechanism of energy release. The nature of solar flares and the realization that the stored energy is magnetic have led to the view, now established for many years, that the energy release is intrinsically an electromagnetic process. Since the flare is an explosive event, we may be more specific and state that the energy release must be effected by a plasma instability. The instability relevant to the present model is the "tearing-mode" instability (6) which leads to a reconnection of magnetic-field lines, thus providing a mechanism by which the open-field lines may rapidly become closed.

One of the difficulties involved in trying to understand solar flares has been an explanation of the very-short time scale of the flash phase (2 to 5 minutes). There is in fact an even-more-difficult problem, that of understanding the time scale of acceleration of electron streams which produce Type-III radio bursts, which have a time scale of about 1 second. The present model is able to meet both requirements. As a result of the very-high conductivity of the coronal plasma, the neutral sheet will be very thin, having a scale of less than 100 meters. The rise time of the instability is correspondingly short, and can explain the 1-second time scale of Type-III bursts. The reconnection of field lines occurs progressively: as one pair of field lines are reconnected, they become subject to forces (mainly mag-

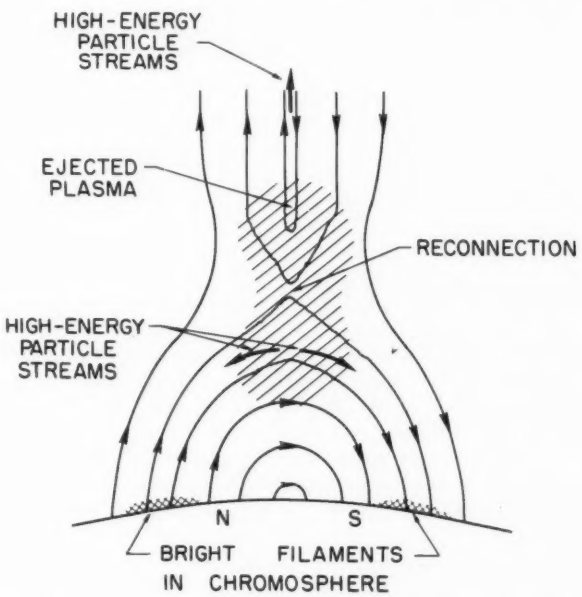

Figure 2. Schematic representation of reconnection of magnetic-field lines during a flare, showing the ejection of plasma and heating of the chromosphere by particle streams to form two bright filaments.

netic tension) which move them away from the region in which reconnection is taking place, so that a new pair of field lines is then reconnected. This is indicated schematically in Figure 2. This problem was studied some years ago by Petschek, (7) who showed that the "merging rate" is about one tenth the Alfvén velocity. The Alfvén velocity in the corona above an active region is typically in the range 10^8-10^9 cm sec^{-1}, so that the merging rate would be 10^7-10^8 cm sec^{-1}. This is fast enough to explain the flash phase of a solar flare.

The fourth question, the explanation of observed properties of solar flares, raises a formidable array of theoretical problems. For the purpose of the present article, we must content ourselves with a very brief sketch of some of the more important effects of field-line reconnection.

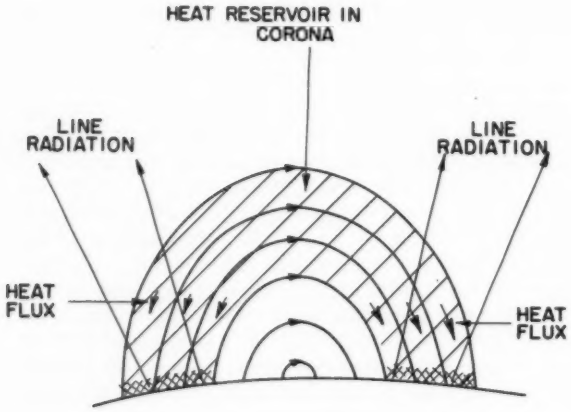

Figure 3. Schematic representation of the decay stage of a solar flare, showing the trapped high-temperature plasma in the corona, the heat flux to the chromosphere, and the enhanced radiation from the chromosphere.

Following flare action, the field pattern shown in Figure 1 takes on the form shown in Figure 3, in which a large fraction of the open-field lines have been replaced by closed-field lines. Since energy has been released during the reconnection process, a large amount of energy is now stored in the trapped coronal gas. This gives rise to an increase in temperature of the trapped plasma to about 10^7 °K, and also to an increase in density above normal coronal values, since an increase in temperature involves an increase in scale height. This mass of hot plasma would constitute a strong source of soft X rays, and would explain X-ray observations of solar flares.

The main mechanism for energy loss by this hot plasma is by thermal conduction down to the chromosphere, where the energy will be lost by increased radiation, primarily in strong chromospheric lines such as Hα. This chromospheric radiation will continue until the coronal gas has cooled to normal coronal temperatures. This represents the "decay phase" of a solar flare.

Following reconnection, the bipolar flux tube which extends into interplanetary space has been reconnected so that the field lines are no longer tied to the photosphere. The plasma in this flux tube now experiences forces (mainly magnetic tension by the open magnetic-field lines) which "catapult" the plasma away from the sun. The ejection of a mass of plasma from the flare region enables one to understand how a solar flare can give rise to a magnetic storm on earth. The shock front which would form in advance of the ejected plasma cloud provides a likely explanation for a Type-II radio burst.

The work involved in developing a theory may be divided into two parts: first, a number of exploratory calculations are made to determine whether the basic hypotheses are correct; and second, more and more detailed calculations should be undertaken when there is reasonable confidence that the basic hypotheses are correct. It is our view that our work on solar flares at Stanford is now moving from the first phase into the second.

Dr. Peter A. Sturrock has been a Professor at Stanford University since 1961. He is presently Professor of Space Science and Astrophysics in the School of Engineering and the Department of Applied Physics. Since 1964 he has been Chairman of the Institute for Plasma Research and, since 1966, Chairman of the Committee on Space Science and Related Programs.

Dr. Sturrock studied at Cambridge University in England where he received his B.A. in 1945, his M.A. in 1948 and his PhD in 1951, in Mathematics. He is a Fellow of the American Physical Society and Royal Astronomical Society, and a member of the American Astronomical Society, American Geophysical Union, and the International Astronomical Union.

The work of Dr. Sturrock is part of a research program on plasma astrophysics sponsored by the General Physics Division, Directorate of Physical Sciences, AFOSR.

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EXISTENCE AND BEHAVIOR OF SIMILAR SOLUTIONS OF BOUNDARY-LAYER PROBLEMS

MAJOR WM. R. TROTT, Directorate of Mathematical Sciences, AFOSR

Boundary-layer theory of fluid mechanics has its basis in the Navier-Stokes equations; the study of the resulting differential equations has attracted the attention of mathematicians for many years. One particular area of interest is the investigation of "similar" solutions of compressible boundary-layer equations which date from 1946 when Illingworth(1) examined the question of what forms of variation of U_1 with X would yield solutions with similar velocity and temperature distributions for different values of X. Here U_1 is the free-stream velocity distribution and X is a coordinate axis. In 1949, Stewartson(2) and Illingworth(3) independently demonstrated that the boundary-layer equations arising from a given main-stream velocity U_1 of a compressible fluid could, by a transformation of coordinates, be converted into the equation for an incompressible fluid with a different main-stream velocity V_1. Thus, solutions known to yield "similar" velocity profiles in incompressible flow readily lead to solutions in compressible flow which are known as "similar" solutions.

Professor James Serrin of the University of Minnesota, under Grant AF-AFOSR-883-67 with the Mathematics Division, AFOSR, has investigated various problems in laminar boundary-layer theory. In two recent papers, written jointly with Professor J. B. McLeod of Oxford University, he examined the existence and behavior of "similar" solutions.(4,5) This research was directed to the boundary layer which occurs in the natural convection of the incompressible fluid adjacent to a heated vertical wall, and to the boundary layer formed by a compressible fluid flowing past a fixed boundary surface. In both cases they considered "similar" solutions of the underlying partial differential equations governing the fluid motion. A major contribution of Professor Serrin's research is the establishment, on a firm mathematical basis, that ordinary differential equations which arise in this way do in fact have solutions satisfying the appropriate boundary conditions for the problems in question. Furthermore, this research effort has provided a mathematical description of the behavior of the solutions for the compressible fluid problem. The latter result includes a rigorous proof, assuming a favorable pressure gradient and no backflow, that velocity overshoot occurs in the boundary layer if the wall is heated, and that this is true whether or not suction, blowing, or slipping occurs at the wall. Conversely, velocity overshoot does not occur when the wall is cooled and the amount of slipping at the wall is suitably restricted.

Boundary-layer theory finds an application in the calculation of the skin-friction drag acting on a body moving through a fluid: for example, the drag experienced by an airplane wing or turbine blade. Other problems of Air Force interest, such as those arising in aircraft stalling and heat transfer, can be approached through a study of the differential equations associated with a boundary layer. In addition, the investigation of flows at very high velocities, i.e., velocities on the order of the speed of sound, which are important for aerospace applications, brings with it numerous problems which are better understood with the aid of mathematical techniques, for example, those indicated by Professor Serrin, applied to boundary-layer theory.

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dayglow profile

AERONOMY LABORATORY, AFCRL

On a dark moonless night away from the city, the faint luminosity of the sky is clearly seen in the contrast of trees and hills silhouetted against it. The luminosity is airglow, or nightglow, and is produced by chemical processes in the upper atmosphere.

These chemical processes are even more active, and airglow is even more intense during the day when atmospheric atoms and molecules absorb solar energy directly. The resultant daytime airglow is called dayglow, and the chemical processes that produce it differ markedly in degree and often in kind from those that produce nightglow. But dayglow, although intrinsically brighter than nightglow, cannot be observed from the ground because of the masking background of Rayleigh scattered sunlight. Even instruments sent aloft in rockets to measure dayglow *in situ* must be carefully designed to shield detectors from other far more brilliant sources of light.

Such an instrument, placed aboard an AFCRL rocket launched from Natal, Brazil, produced the sharpest atmospheric profile of dayglow yet obtained. The profile extended from 70 to 220 km (See Figure 1). The launch from the Brazilian site permitted comparisons to be made of the altitude profile for dayglow in the equatorial region with previous profiles obtained at midlatitude and Arctic regions.

Dayglow is produced over a range of distinct infrared and visible wavelengths, depending on the atmospheric constituents involved in the chemical reaction. In the AFCRL experiment, measurements were made of emissions involving oxygen reactions. These reactions produced a strong emission at 5577 (green line) angstroms. The atmospheric profile of 5577-angstrom emissions showed that emissions were most pronounced at an altitude of 95 km where a peak emission rate of 330 photons per cubic centimeter was measured. About 40 percent of the total dayglow emission at 5577 angstroms occurred within a 23-km-altitude range centering at this peak. Two weaker emission layers were observed at 170 and 200 km, producing about 75 and 100 photons per cubic centimeter, respectively. These equatorial-region profiles were consistent with profiles measured at other latitudes, except that the 200-km peak appeared to be much more pronounced in the equatorial region.

The schematic arrangement of the photometers aboard the rocket required a little trickery to mask out normal scattered sunlight. Light from two neighboring spectral regions, 5577 and 5530 angstroms, entered through a series of baffles, iris diaphragms, filters and lenses, and passed separately through a rotating shutter to a detector. The 5530-angstrom segment served as a base reference for the 5577-angstrom line.

Three kinds of oxygen reactions are probably involved in producing the observed dayglow at 5577 angstroms. The emission at 95 km is primarily the result of collisional mechanisms involving atomic oxygen, while reactions at higher altitudes are probably due to the dissociative recombination of O_2^+ or the excitation of O_2 by photoelectrons.

Airglow is only one kind of optical radiation in the upper atmosphere that adds background noise affecting the performance of delicate IR and visible sensors aboard satellites. The aurora, zodiacal-light, and stellar, lunar and planetary emissions are all sources of light contamination which must be taken into account by the designers of sensors and associated surveillance equipment.

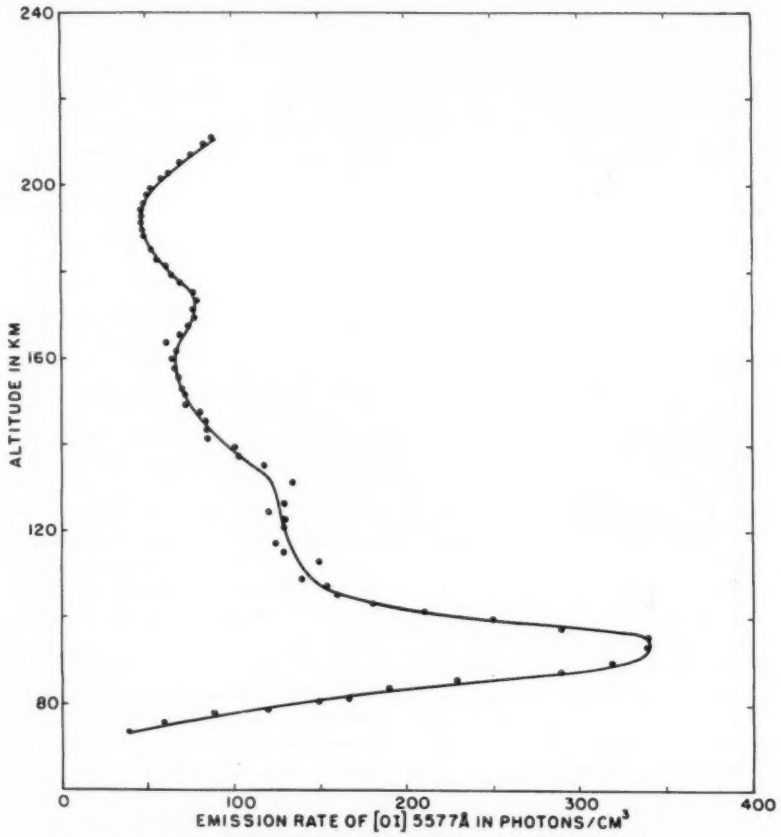
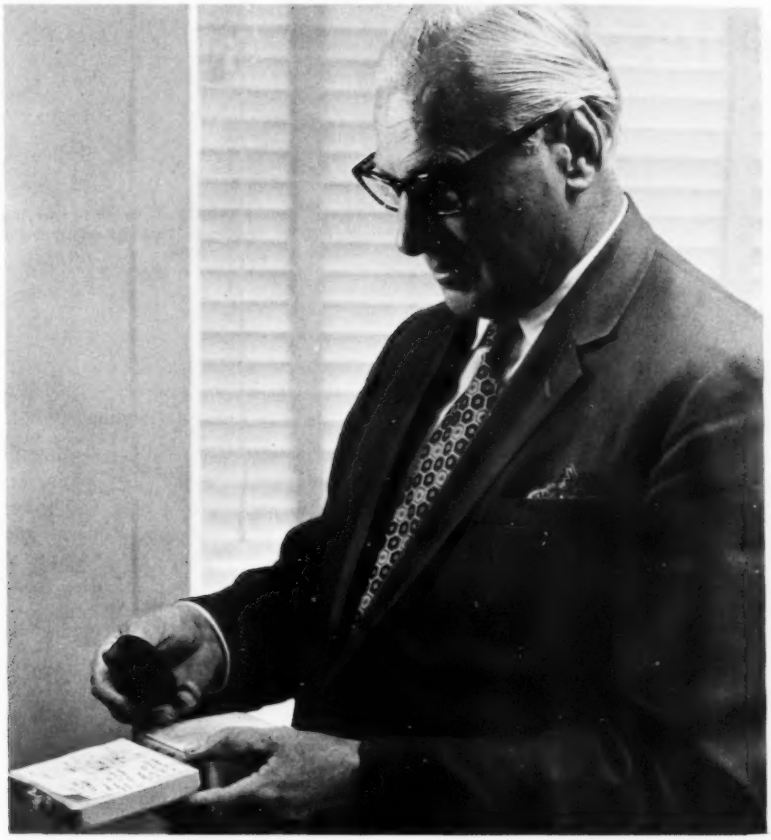


Figure 1. Distribution of dayglow emissions as a function of altitude.



Hydrogen Gas Generator for Field Use

AEROSPACE INSTRUMENTATION LABORATORY, AFCRL

In 1962 AFCRL developed a new portable system for generating hydrogen gas which is now used by Air Weather Service personnel and other meteorologists all over the world. The generator is designed to provide hydrogen for inflating meteorological balloons. It has become a standard meteorological equipment in remote areas, most notably in Antarctica. Now AFCRL, jointly with Engelhard Industries of Newark, N.J., has redesigned and improved the generator.

Generating systems in use before 1962 were both dangerous and inefficient. The AFCRL generator is safe, efficient, and economical to operate. Hydrogen is produced by the heat cracking of anhydrous ammonia. The ammonia-cracking generator produces a gas mixture of three parts hydrogen and one part nitrogen through endothermally splitting ammonia by the use of a platinum catalyst and heat supplied by an oil burner. The reaction is:

$$2NH_3 + \text{Heat} + \text{Catalyst} = 3H_2 + N_2.$$

The liquid-ammonia feed stock is forced into the vaporizer of the generator by the vapor pressure within the supply cylinder. The vaporized ammonia then passes to a high-temperature alloy retort containing the catalyst where the cracking process occurs. One pound of ammonia yields about 33.5 cubic feet of hydrogen plus about 10 cubic feet of nitrogen, enough to inflate one standard radiosonde balloon. The cost of the generated gas is about 50 to 60 cents per flight.

The equipment, which is designed to be portable, weighs about 1,000 pounds and has dimensions of approximately 3 feet long, 3 feet wide, and 3 1/2 feet high. The gas output rate is 400 cubic feet per hour.

The system is now being improved to eliminate the relatively high yield of nitrogen produced along with the hydrogen. Nitrogen has a molecular weight very similar to that of air, and its presence in the inflation gas is "excess baggage" that results in a balloon height penalty of about 5 percent.

In the improved system, nitrogen is removed by diffusion. The diffusion process is accomplished by a palladium-silver-alloy tubing in the chamber generator. As the hot pressurized gas flows through this tubing, the hydrogen diffuses through the walls and is collected in pure form. The nitrogen and other impurities are bled out of the end of the tubing and vented.

Konstantins Pocs is a research physicist at the Aerospace Instrumentation Laboratory, AFCRL. His most notable contribution to meteorological equipment has been in the development of small meteorological rockets. He has also improved the design of a hydrogen gas generator for inflating meteorological balloons to be used at remote weather observing stations. He is currently concerned with the research and development of equipment for meteorological balloons and rocket sounding systems.

Mr. Pocs received his B.S. in Physics from the University of Riga, Latvia, in 1938, and two years later his M.S. in Physics from the same University. He also did predoctoral work at the University of Goettingen, Germany from 1945-1947, and subsequently took other postgraduate courses in England and Canada.

Prior to his employment by AFCRL in 1962, Mr. Pocs had been engaged in the design and development of power transistors, diodes, and rectifiers. He is a member of the Institute of Electrical and Electronics Engineers, and has published several papers on his work.

How Hailstones Grow

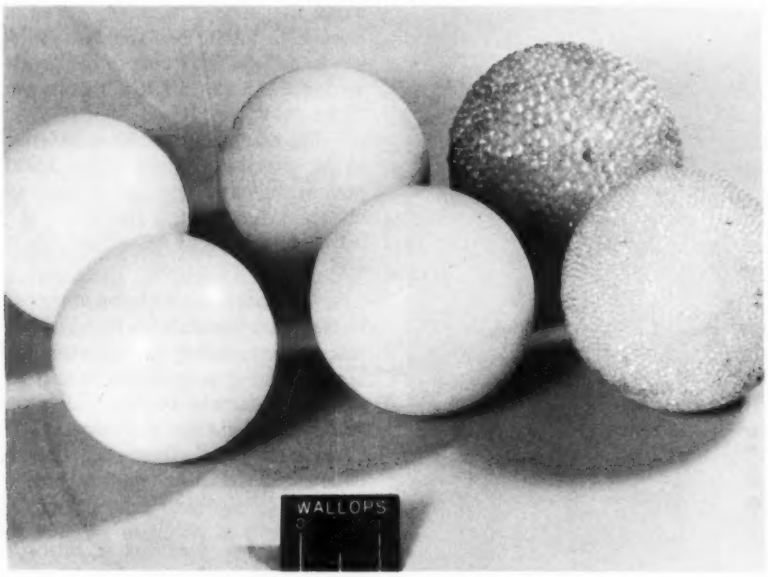


Figure 1. Six plastic balls with varying degrees of roughness, used to evaluate the rate of fall of hailstones.

METEOROLOGY LABORATORY, AFCRL

High-school science textbooks taught us quite a bit about the growth of hailstones. We learned that hailstones have an onion-like structure due to the sequential accumulation of moisture at lower parts of the cloud, followed by the freezing of this moisture after the hailstone had been caught in the intense upward convection and transported to the colder upper part of the cloud. And we learned that through this recycling process the hailstone can grow to grapefruit size.

Implicit in this neat model is the assumption that either the convective winds at the base of the hail-bearing thunderhead are much stronger than those in the upper region, or that the hailstones become trapped in a kind of closed loop of updrafts and downdrafts. Neither explanation is complete, given the physics of the situation and our present knowledge of the internal wind structure of large thunderheads.

This problem relating to the growth of hailstones was the basis for a study conducted by AFCRL during July and September of 1968. The study involved the dropping of simulated hailstones from altitudes of about 25,000 feet and tracking their rate of fall by radar. This study was conducted over the Atlantic Ocean 6 miles east of Wallops Island, Virginia. The hailstones varied in roughness, weight, volume, and shape, and ranged in size from about 1 inch to almost 4 inches in diameter. Terminal velocity of the hailstones was measured as a function of their shape, size, and roughness.

In wind-tunnel tests made several years ago, it was shown that shape and surface roughness can profoundly affect the falling speed of an object by changing its drag characteristics. Contrary to expectation, it was found that the terminal velocity of a smooth sphere, for example, is much less (by as much as one third) than that of a sphere which has a dry, rough surface. This fact has helped in the formulation of theories explaining the growth of a hailstone in a convective cloud.

As the hailstone embryo falls through the cloud, it plummets through regions of higher and lower water content and varying updraft and downdraft velocities. In a region of high cloud-water content, the stone may acquire a thin, smooth coating of water, causing its rate of fall to decrease and allowing it to grow faster over a given height interval. It may then pass through a colder region of the cloud where the water coating freezes and the stone subsequently becomes roughened by the accretion of small dry-ice particles. This roughened surface results in a greater terminal velocity and the hailstone begins to fall more rapidly. The cycle may be repeated a number of times. However, even this oversimplified explanation fails to account fully for the giant hailstones sometimes found.

AFCRL hopes to obtain precise information on the terminal velocity as a function of sphere characteristics, and to apply this knowledge toward a better understanding of the growth mechanism of real hailstones.

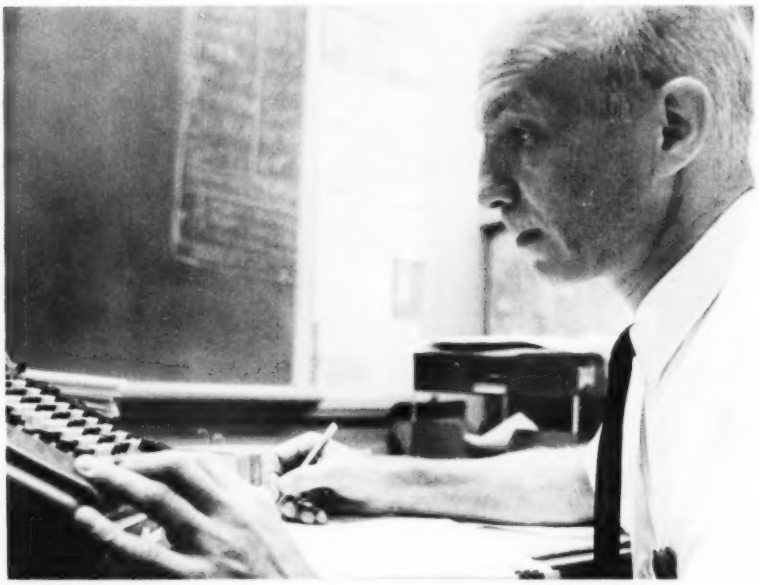
Mr. C. R. Landry, a meteorologist since 1960 in the Weather Radar Branch, Meteorology Laboratory, AFCRL, conducts research on circulations within storm systems and the radar detection of such circulations. He has conducted many studies on the growth of hailstones.

Mr. Landry attended various meteorological courses in the Air Force and served with the Air Weather Service from 1956 to 1958, doing typhoon reconnaissance in the Pacific. He is a member of the American Meteorological Society.

The photographs on the wall in Mr. Landry's office show the variety of forms that hailstones can assume.

AEROSPACE INSTRUMENTATION LABORATORY, AFCRL

Pressure Surfaces And SST Passenger Discomfort



A mildly cautionary note on supersonic-transport (SST) operations was raised by Arthur J. Kantor of AFCRL in a brief article recently submitted to the magazine, *Weatherwise.* The article discusses slopes of pressure surfaces at SST altitudes, a problem that relates back to the conventional barometric altimeters aboard the aircraft.

Such altimeters, as every pilot knows, do not measure absolute altitude, but merely the atmospheric pressure—which is closely correlated with absolute altitude—sufficiently close so as not to be a problem in subsonic flight. Because atmospheric pressures vary along an absolute altitude plane, the pilot actually ascends or descends in altitude while his altimeter reading remains constant. So gradual are these changes in altitude that the passengers and the pilot in subsonic aircraft are seldom aware of them.

But consider an SST restrained by a sophisticated guidance system to a constant pressure altitude of, say, 64,000 feet (60 mb), and a speed of Mach 3. Over a given distance, the constant pressure surface may ascend or descend sharply relative to SST speeds. Kantor selected as an example a case of an absolute altitude change of 272 feet within a 4-mile distance, a magnitude derived from a scientific treatment of atmospheric structure on the lee side of the Rockies during strong upper airflow. At Mach 3, the 4-mile stretch would be covered in about 8 seconds. This change could produce a g-force of 0.25 (an acceleration of 8 feet/sec^2). As a general rule, passenger discomfort sets in when a g-force of 0.2 is exceeded.

In addition to the pressure slope problem at SST speeds, Kantor suggests that vertical motions of the atmosphere, producing undulations of a wave type, is another phenomenon occurring at this altitude which may be important at SST speeds and which must be critically evaluated for SST flights.

Mr. Arthur J. Kantor has been a meteorologist in the Design Climatology Branch of the Aerospace Instrumentation Laboratory, AFCRL since October 1960. He is currently engaged in work on applied climatology, and is considering problems on the variability and interrelationships of atmospheric parameters. He is also developing theories on upper-atmospheric structure.

After receiving the degree of B.S. in Meteorology in June 1950 from Pennsylvania State University, he pursued graduate courses at Rutgers University in 1956 and at the Massachusetts Institute of Technology in 1961, 1962, and 1964.

From 1951 to 1960, Mr. Kantor worked successively for the Irish Meteorological Service, the U.S. Navy Hydrographic Office, the U.S. Weather Bureau, and the U.S. Air Force. He is a member of the American Meteorological Society.

Recent High-Speed Gas-Dynamic Research at The von Karman Institute for Fluid Dynamics

MAJOR RICHARD T. BOVERIE, EOAR

INTRODUCTION

The von Karman Institute for Fluid Dynamics is a NATO institution located in Rhode St Genèse, near Brussels, Belgium. The Institute, founded by Dr. Theodore von Karman in 1956, was originally called the Training Center for Experimental Aerodynamics. It seeks to give scientists and engineers from the NATO countries specialized training in the techniques and practices of a modern aerodynamics laboratory. It also conducts a vigorous research program in experimental aerodynamics and fluid dynamics, much of which is carried out under contract with industrial companies and government organizations of the various NATO countries.

The Director of the Institute is R. O. Dietz. During an aerospace career of more than 20 years, Dietz was involved in aeropropulsion research at the former NACA, in internal flow and propulsion research with ARO Inc., and in theoretical scientific research as a civilian employee of the U.S. Air Force. The Technical Director of the Institute is Professor J. J. Smolderen, and the Associate Director is Professor P. E. Colin.

Some of the more important research programs being conducted at the Institute are described below.

LAMINAR SEPARATION AT HYPERSONIC SPEEDS

Professor Jean J. Ginoux has been investigating the effect, on the reattachment pressure and heat-transfer peaks, of the injection of air and foreign gases into the separated region of the laminar flow over a cone-cavity model at high Mach numbers.

For a number of years it has been known that the presence of a cavity in the surface of a hypersonic body produces a significant redistribution of surface pressure and heat transfer to the body. Specifically, these quantities are reduced in the region of separated flow, but increase sharply in the vicinity of reattachment, followed by a decrease toward the undisturbed values in the downstream area. The elevated pressure and heat transfer at reattachment constitute the primary undesirable feature of this phenomenon, justifying further research into methods of substantially reducing these peak values.

Ginoux and others have previously theoretically predicted and experimentally verified that the injection of a small amount of gas (a fraction of the mass flow in the boundary layer at separation is sufficient) into the separated region accomplishes this reduction. He shows that the lighter the gas, the larger the rate of decrease of peak pressure. Also, lighter gases are more efficient than heavier ones in reducing heat transfer to the body surface. Actually, the relative effectiveness of various gases in reducing pressure and heat-transfer peaks is surprisingly similar. Thus, the effectiveness of the various injection gases tested by Ginoux—hydrogen, helium, air, freon, and carbon tetrachloride—on reducing reattachment pressure and heat-transfer peaks can be correlated by a single factor which is a function of the molecular weight of the injected gas. Values of this factor, calculated from various published theories and experiments for laminar and turbulent unseparated flows, support Ginoux's most recent data.

INFLUENCE OF CROSS FLOW ON SEPARATION

Ginoux is also investigating the influence of cross flow on two-dimensional separation. The investigation is basic research with practical applications to the problem of interaction between laminar boundary layers and swept shock waves as it occurs in hypersonic inlets or on fins on hypersonic wings.

One immediate objective is to investigate the effect of a small amount of cross flow on two-dimensional laminar separation. However, because of end effects, a basic investigation of this problem could not be satisfactorily performed on two-dimensional models. Ginoux therefore conducted the investigation on rotating axisymmetric models, with angular velocities up to several thousand rpm and at free-stream Mach numbers of 2.2.

Recently, Ginoux satisfactorily tested a model, 200 mm in diameter, rotating at 5,000 rpm in the 400 by 400-mm-square test section of his supersonic wind tunnel. He plans future measurements of static pressure distributions and studies of flow visualization. He also intends to compare, systematically, the several analytical methods for calculating pressure distribution through a shock wave-laminar boundary layer interaction.

LOW-DENSITY, HIGH-TEMPERATURE GAS DYNAMICS

Prof. J. J. Smolderen and Dr. John Wendt have developed and are using a technique which permits accurate measurement of certain flow properties under low-density conditions. The technique relies on the fact that modulating a physical effect of interest and processing the resultant a.c. output with a tuned amplifier–synchronous demodulator combination can effectively eliminate not only electronic noise and pickup, but also source or transducer drifts. It is a clean technique for recovering useful information from an otherwise hopelessly noisy signal.

The modulation technique has proven most successful

in measuring forces in rarefied flows. Force levels as small as a few tenths of a milligram have been measured with a sensitivity of 1% under wind-tunnel operating conditions. The device is now being used to determine the drag coefficients of spheres, cylinders, and cones in hypersonic rarefied flows. Modulated hot-wire probes have proven useful for qualitative flow surveys, and cold-wire probes will hopefully be able to provide quantitative information on local mass flux and speed ratio. First-collision experiments, or experiments in which the small deviations from free-molecule data are measured directly, appear feasible with the aid of the modulation technique.

Smolderen and Wendt are also studying the aspects of three distinct types of low-density flow problems which touch upon the major areas of interest in rarefied-gas dynamics–rarefied flows around bodies, nonequilibrium free-jet expansions, and gas-surface interactions. In addition, they are investigating the possibility of measuring accommodation coefficients on engineering surfaces in hypervelocity flows. A preliminary theoretical study has been conducted, using a simple gas-surface model, to gain a better understanding of the relationship between thermal and tangential momentum accommodation.

The Institute's low-density facility, which was constructed in 1963, is a wind tunnel that produces rarefied hypersonic flow. It has a maximum pumping speed of 20,000 liters per second in the chamber pressure range from 1 to 5 microns of mercury. The test chamber itself consists of a cylindrical vacuum tank 50 inches in diameter and 70 inches long. A probe traversing mechanism, remotely operated by selsyns and having two degrees of freedom, is also mounted in the tunnel. The laboratory is well equipped with the most advanced types of vacuum instrumentation.

SUPERSONIC COMPRESSORS WITH SUPERSONIC AXIAL INLET VELOCITIES

Professor J. Chauvin and Dr. F. Breugelmans are investigating transonic-supersonic compressor rotors, using the blunt-trailing-edge concept. Earlier proposed solutions for high-speed flight inlets use a supersonic diffuser, throat, and subsonic diffuser to feed the engine. The inlet is matched to the engine over the Mach range by bypass, bleed doors, and variable centerbody.

Chauvin and Breugelmans have shown that the payload capacity of a supersonic design is most sensitive to cowl-lip and nacelle wave drag, boundary-layer-bleed drag, and inlet-total-pressure recovery. Although the internal compression inlet has the best pressure recovery, it is not the best configuration because of an excessive bleed-drag coefficient and skin friction.

A promising configuration, considering weight and pressure recovery, would be an engine that accepts supersonic axial inlet velocities, and is installed in an inlet which decelerates the flow only to an axial Mach number moderately above one. Recent progress in the aerodynamics of supersonic compressors, and the materials involved, makes feasible the investigation of a front-stage compressor with supersonic axial velocity.

Current work consists of blade-element research in cascades and rotors employing freon gas in a closed circuit.

Another important factor being investigated is the stability of the shock system inside the passage, with variations in back-pressure. The crossing of the two leading edge shocks in the passage inlet region can create problems not yet encountered in supersonic compressor work. At moderate axial inlet Mach numbers ($\simeq$1.25) one shock disappears as soon as the other strong shock is formed at the leading edge. At higher axial Mach numbers, complete crossing occurs.

"LONGSHOT" FREE-PISTON HYPERSONIC TUNNEL

Of particular interest is the "Longshot" free-piston hypersonic tunnel, originally developed by Dr. R. Perry of Republic Aircraft Corp.; it is now operating in modified form at the Institute. It can generate extremely high Reynolds-number hypersonic flows for the simulation of reentry vehicle flight, especially during the critical stages of maximum heating and deceleration of the vehicle. Principal tunnel work has been done by Dr. K. R. Enkenhus and Dr. B. E. Richards.

Free-flight dynamic stability tests of a 30° half-angle cone have been made in Longshot at Mach 19. The model, constructed with a lead nose tip and a Clocel plastic frustum, is suspended by fine threads at an initial angle of attack at the nozzle exit. When the flow starts, the threads break, and the model executes pitching oscillations as the tunnel airstream and the model drag cause it to travel downstream through the test section. The oscillations are photographed by a camera with a framing rate of 1600 pictures per second. The variations of the local dynamic pressure and flow velocity as the model traverses the test section are determined from previous tunnel calibrations. The pitching moment coefficient, C_{M_α}, and the damping in pitch derivative, $C_{M_\alpha} + C_{M_q}$, are determined by a comparison method. Numerical integrations of the equations of motion are made on the Institute's IBM 1130 computer for a range of values of the stability derivatives, until the experimentally observed motion is matched. The good agreement obtained between the predicted and measured stability derivatives indicates the usefulness of the technique. Although the models tested would exhibit damped oscillations in a uniform flow, these oscillations do not appear in Longshot because of the conical (expanding) flow field and decaying supply conditions. Correct values of $C_{M_\alpha} + C_{M_q}$ are obtained by taking into account the falling dynamic pressure as the flight proceeds.

AIR FORCE SUPPORT

The Air Force Office of Scientific Research is supporting in part Ginoux's research on laminar separation, and that of Smolderen and Wendt on low-density gas dynamics. The Aerospace Research Laboratories are supporting the research by Ginoux on the influence of cross flow on separation, and the research of Chauvin and Breugelmans on supersonic compressors.

the ordering of the solar system

SPACE PHYSICS
LABORATORY, AFCRL

The planets are arrayed outward from the sun at related mathematical distances. Why this relationship should exist has puzzled all those who have considered the matter, and no one has come up with a fully satisfying answer.

A new gravitational theory formulated by C. C. Leiby, Jr., of AFCRL has been applied to the problem. (See the article, "An Explanation of Gravity," which appears in this same issue.) The gravitational theory states that, in addition to the familiar Newtonian gravitational field, there is a second component—very weak—that can be considered the analog to a magnetic field. He calls this component the "gravinetic" field. This field permits one to treat gravitational interactions between moving masses in the same manner as one treats the electromagnetic interactions between oppositely charged moving particles.

The significance of this is that one has a theoretical tool for assuming mutual inductances among the planets. Leiby postulates, in fact, that all the planets are inductively coupled, and therefore the planets will tend to order themselves in a kind of harmonic relationship. Thus, if one knows the "frequency" of an arbitrarily chosen planet, one can derive the "frequency" of the others. The forces at play in the ordering of the solar system are not related to the gravitational field of the sun.

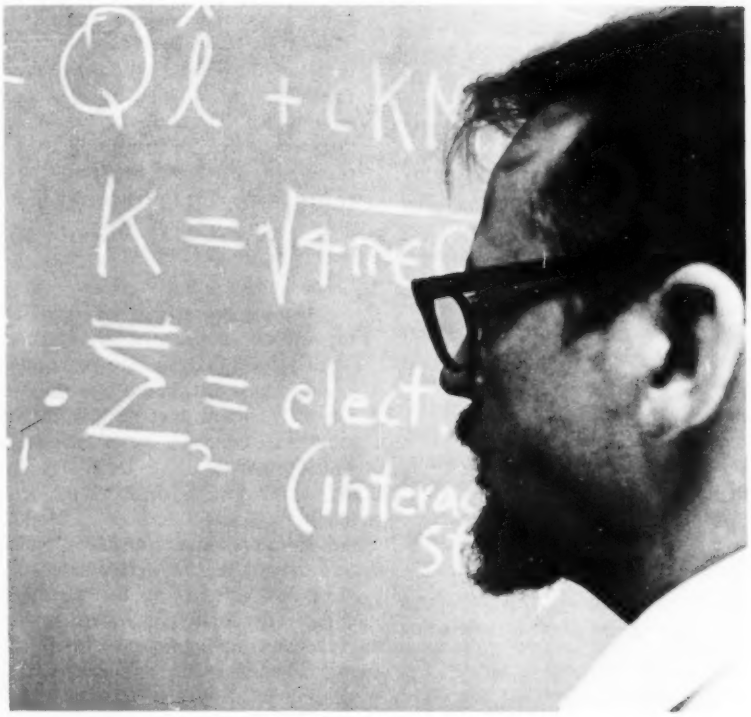
Leiby suggests that we may treat the orbital motions of the planets—when viewed on a million-year scale—as uniformly distributed *mass* current loops. We know that electric current loops exert torques upon each other which tend to make their magnetic moments align. The magnetic moment, in the gravinetic analog, is angular momentum. However, angular momentum cannot be transferred from one planet to another if we assume a uniform orbital mass current flow. For inductive coupling (and the transfer of angular momentum and energy that this implies) between orbits to occur, the current flow must vary in time—that is, we must have an alternating current. This a.c., or time, variation is determined by the velocities of the planets in their orbits and is propagated through space at the speed of light. The shortest wavelength associated with these induction fields is produced by Mercury, the planet with the smallest orbit. The Mercury orbit produces a wavelength of 10^{16} meters. Because the diameter of the solar system is less than 10^{13} meters, all the planets may be considered to be inductively coupled.

If we take just two planets—Mercury and Jupiter—as examples, we would expect, given the foregoing model, that Mercury would adjust one component of its motions to the frequency of Jupiter's field. In analogy to an electron in an a.c. field, this component would reach a steady-state oscillatory motion 90 degrees out of phase with the induction field and would absorb no further energy. However, two effects mitigate against such a phase relationship. First, since Mercury's orbit is eccentric, its orbital motion must be characterized by a spectral distribution of frequencies. Thus, a final harmony between Mercury and the induction field of Jupiter cannot be achieved until this eccentricity is "damped out" by the induction interaction. Second, even if this eccentricity were completely removed, Mercury could still not maintain a completely out-of-phase relationship with Jupiter's induction field, owing to the perturbations on its motion arising from the gravitational fields of the remaining planets.

From this, one may infer that a time will come when no further net energy and momentum transfer will occur between the planets. Their orbits will all be circular and coplanar, and their orbital periods will exhibit some harmonic relationship. The planets do in fact exhibit such a general relationship which can be represented in a logarithmically periodic structure. One can use this structure to analyze the solar system and to make predictions. In Leiby's log-periodic representation, five harmonic orbits are not occupied by planets: the first and third orbits on either side of Jupiter are not occupied, and a fifth vacant orbit exists between Mercury and Venus.

These orbits, however, may not be vacant, but may be "filled" by comets, asteroids, and debris that have established harmonic relationships by inductive coupling with the major bodies of the solar system. Leiby points out that the 30 satellites or moons of the planets are also arrayed in a mathematically related fashion outward from their parent planets, and believes that his inductive coupling theory can account for these alignments.

If the log-periodic relationship formulated by Leiby is correct, most of the planets must move somewhat closer to the sun. Jupiter, because of its enormous mass, should remain essentially where it is, while Saturn and Uranus must move somewhat away in order to achieve precise harmonic relationship. However, except for Mercury and Pluto, the present eccentricities and inclination of the planetary orbits are very small. Thus one might conclude that the ordering process is nearing completion, and that the present relationships between planetary periods are not far from their final harmonically related steady states.



Mr. Clare C. Leiby, Jr., has been employed since June 1964 as a physicist in the Energetics Branch of the Space Physics Laboratory at AFCRL. Prior to coming to AFCRL, he had spent some time at the Sperry Rand Research Center developing diagnostic techniques to investigate high-electron-density plasmas. Currently, he is working on theoretical and experimental studies for the acquisition of fundamental knowledge of transport phenomena in the plasma state of matter.

Mr. Leiby received his B.S. in Physics in 1954 from the Massachusetts Institute of Technology, and his M.S. from the University of Illinois in 1958. He has also completed his course requirements for a Ph.D. in Physics. He has several papers to his credit.

AN EXPLANATION OF GRAVITY

SPACE PHYSICS LABORATORY, AFCRL

Einstein spent most of his later years searching for relationships between two of the fundamental forces of nature–electromagnetic and gravitational forces. To the physicist, the search is the most intriguing, most difficult, and often the most frustrating in all of science. Partly by intuition, he knows that a relationship must exist and must be explained. Still, his deepest and most ingenious insights have led him, often by lengthy mathematical excursion, only to an inconclusive destination where his theory can be neither proved nor disproved.

C. C. Leiby, Jr., of AFCRL has brought a new perspective to the search– a search, really, for an explanation of gravity, at least to the extent that electromagnetism has been explained. Leiby's theory has evolved through several papers over the past two years, but is contained in its most complete form in a recently published AFCRL report, "Gravity and Electric Charge," *AFCRL-68-0581*. A product of the theory is its application to a representation of the ordering of the planets in the solar system (discussed in the article, "The Ordering of the Solar System," included in this same issue.) This representation is superior to that of Bode's Law, the classic work on mathematical relationships of the distances between planets.

Leiby assumes, as do most theorists, that electromagnetic and gravitational fields are somehow related. This assumption would imply a unified source, one capable of characterizing both gravity and electromagnetism. The source, if found, would be found in the long-lived atomic particle–the electron, the proton, and the neutron. But, while electromagnetism is concerned with coulomb or charged interactions between particles, gravity is concerned with mass interactions. Thus, a mathematical model of an atom must be found that enables us to deal with the mass and charge as a single entity.

Why do theorists insist on a hidden relationship between gravity and electromagnetism in the first place? Apart from compulsion to find symmetry and simplicity, the most compelling evidence is that both gravity and electromagnetism obey the inverse-square law which says that the force of both fields decreases with distance in the same mathematical relationship. And both seem to propagate with the speed of light, although there is some residual uncertainty as to gravity.

But there are differences as well. Electromagnetism consists of two

identifiable and measurable components, an electric field and a magnetic field. Gravity, however, seems to have only one component, the familiar Newtonian gravity that holds us on earth with a force of one g, and that keeps satellites in orbit. Moreover, electric charges both repel and attract, whereas gravitational forces between masses are always attractive. Leiby's theory has its origin in this latter difference. He has developed a unified-source function for electrically charged masses which takes this difference into account. When inserted into Maxwell's equations, this function generates the familiar electric, magnetic, and Newtonian gravitational fields *plus* a gravitational analog to the electromagnetic field. What characteristics would this gravitational magnetic analog have? When two masses move in some relationship to one another, would we expect to see some analog to the inductances, currents, and complex effects of the type found in electric- and magnetic-field interactions? It would seem unlikely because Newtonian gravitation theory has succeeded in representing all the interactions between gravitational masses in a highly satisfactory manner. The effects of the second gravitational component, however, may simply be too small to measure.

Leiby's analysis led to a second gravitational component. He has designated this component the "gravinetic" field, and the familiar Newtonian component, the "gravilectric" field. He suggests that the postulated field can be called upon by theorists to deal with a range of problems, foremost of which is the problem concerned with the transfer of angular momentum by induction. The effect of the field is negligible except on a cosmic scale of time and when dealing with large masses–the solar system and galaxies. Nevertheless, the gravinetic field permits theorists to treat interactions between masses in the same manner that they treat interactions in electromagnetic studies.

To relate gravitation and electromagnetic phenomena to a common atomic source, Leiby has constructed a model of a unified-source function consisting of a vector in an (abstract) complex space. This vector is derived from three fundamental complex vector sources for the electron, proton, and neutron. The appropriate source function for a particular atom is then characterized by the vector sum of these three vectors.

Although the Leiby atom is characterized by the sum of electron, proton, and neutron charge vectors which describe both mass and charge, Leiby notes that these are not simple sums, but involve terms from atomic and nuclear binding energies as well, since these energies of themselves possess gravitational mass. He notes that the "elementary-particle mass formula prediction by the SU(3) theory depends upon the same internal quantum numbers as the formula for charge." This suggests that later work may uncover further relationships that tie in with the other two fundamental forces of nature, namely, the strong and weak forces in the atomic nucleus. Thus there may be shown to exist a unity among all the forces of nature. However, the inclusion of nuclear binding forces in Leiby's representation must await future discoveries concerning the relationship between strong interaction forces and the forces of gravity and electromagnetism.

The application of Leiby's complex vector source functions to Maxwell's equations leads to predictions concerning the nature of gravitational radiation, just as we can predict the behavior of electromagnetic radiation from these same equations. But when we consider gravitational fields at the atomic level, we are dealing with very small effects indeed. The relative values of these effects have been calculated and are well known to those who have studied this area of physics. (For example, the magnitude of the gravitational energy radiated by an accelerated electron is only some 10^{-43} times as large as the electromagnetic energy which it simultaneously radiates. For the proton, the comparable figure is 10^{-37}.)

The product of these very small effects, however, may be observed on a cosmic scale of time. Such a product is discussed in the article, "The Ordering of the Solar System," which appears in this same issue of the *Review*.

Forecasting the Magnitude and Duration of Polar-Cap Absorption

IONOSPHERIC PHYSICS LABORATORY, AFCRL

A new method for forecasting the magnitude and course of polar-cap absorption (PCA)—a condition of severe radio disruption in the arctic—was recently described in a paper by Ming S. Wong of AFCRL. The scheme provides short-term predictions of up to 2 days, sometimes with accuracies to within 10 percent. The primary instrument for making the prediction is the riometer, automated to give data on real time. The riometer is nothing more than a small radio receiver that monitors normal background galactic radio emissions. Decreases in the signal strength of galactic background radiation are a measure of increased ionospheric absorption; absorption, in turn, is a measure of electron density in the ionospheric D region. Increased electron density is a basic PCA effect.

The prediction method has direct application to the Space Forecasting System—a new Air Force system under development by AFCRL and the Air Weather Service. The Space Forecasting System is designed to forecast all naturally occurring phenomena likely to affect Air Force operations, phenomena which include energetic-particle fluxes, geomagnetic disturbances, sudden ionospheric disturbances, auroral activity, and so on. Many of these phenomena are related to PCA. They can severely degrade the performance of surveillance radars, navigation systems, and communications. PCA has its origin in bursts of high-energy protons from the sun. These protons, guided by the earth's magnetic field, enter the earth's atmosphere in the polar regions.

The method described by Ming Wong does not predict the onset of a PCA event, but only its course and intensity, once it has begun. Peak effects occur within hours of the onset, but then trail off, sometimes lasting four or five days. The first step in the prediction scheme is to make an estimate of when peak ionospheric absorption will occur. This initial estimate is derived from data provided by solar radio telescopes that detect solar radio bursts in the centimeter-to-meter-wavelength region. These bursts herald the onset of the PCA event. Once ionospheric absorption sets in, riometer data are correlated with solar radio burst data to obtain the earliest possible estimate of peak absorption.

From the peak period of ionospheric absorption until noon the next day, the predictions are least accurate, primarily because of the changing characteristics of the incoming solar proton flux. Another complicating factor involves the normal diurnal radiations in electron density. The prediction scheme requires data from several high-latitude riometer stations. Each riometer, operating at 30 MHz, looks vertically upward. The incoming absorption values from each riometer station are extrapolated ahead in time, with negative exponential weighing of the data according to the age of a data point.

Mr. Ming S. Wong is a research physicist at the Ionospheric Physics Laboratory, AFCRL. His work there since 1957 has included studies of tropospheric and ionospheric propagation, ray tracings in anisotropic media, wave theory, and techniques for the short-term forecasting of the ionospheric propagation of radio waves. Recently, he developed a method for forecasting the magnitude and duration of polar-cap absorption.

In 1938, Mr. Wong received his B.S. in Electrical Engineering from the University of California in Berkeley, and the following year his M.S. in Electrical Engineering from Iowa State University. He has several papers to his credit.

THE MEN BEHIND THE MACHINES: A Survey of Information-Processing Personnel

ROWENA W. SWANSON,
Directorate of Information Sciences, AFOSR

Three generations of computers have been born and have developed robustly in less time than that of one human cycle. Their birth, growth, and applications have been documented meticulously. They have been personified, praised, and defended by proud parents and relatives, and a burgeoning literature has grown up about them.

By contrast, the humans who give the computers life as designers, programmers, engineers, operators, etc., are in comparative anonymity. Who are they? What educational backgrounds and personality characteristics do they have that stimulate them to be attracted to computers and particularly suit them to work with computers? What jobs do they perform? What curricula are being developed to educate and train them? How do they fare economically? What effects are increasing numbers of computers having and going to have, not only on today's information-processing personnel, but also on the uninitiated destined voluntarily or involuntarily to join them?

People who have been involved in various aspects of computer design, operation, and use have been forming professional societies and groups within existing societies and have, to some extent, been introspective about themselves. One of these groups, the Computer Personnel Research Group of the Association for Computing Machinery (ACM) has, since 1962, been concerned with the identification, selection, development, and evaluation of computer personnel. The Group has sponsored studies and conferences that have examined relevant topics in this area. (1) Professional and trade journals have published details on curricula and occupational categories. (2, 3) Only recently, however, has there been a large-scale, planned project to acquire data on the varied communities of people who constitute, as a totality, the information-processing personnel.

In 1967, the Information Processing Techniques Branch of the Advanced Research Projects Agency (ARPA), Department of Defense, through the AFOSR Directorate of Information Sciences, sponsored a questionnaire survey of the membership of seven professional societies in the information processing field. The study was conducted by the American Federation of Information Processing Societies (AFIPS) with which five of the professional organizations were affiliated. The AFIPS societies surveyed were: the Association for Computing Machinery, the American Society for Information Science, the Computer

Group of the Institute of Electrical and Electronics Engineers (IEEE-CG), the Special Libraries Association, and Simulation Councils Inc (SCI). The Data Processing Management Association and the Numerical Control Society also participated.

The AFIPS report of the survey was recently published. (4) It contains data compiled from 29,826 questionnaires, with the data presented in 5 major categories: personal data, education, employment, professional activities, and salary and income. Figures 1 through 8 summarize salient statistics. Some perhaps unexpected findings include the high proportion of men to women among information personnel (Figure 1), and the lower incidence of mobility than many commentators on personnel turnover have heretofore suggested as characteristic of this field (Figure 7). Figure 8 compares the AFIPS data with those obtained in a membership study conducted in 1960 by the Professional Group on Electronic Computers (PGEC) of the Institute of Radio Engineers. (5) In the 1968 survey, the two societies having the highest populations of engineers were the IEEE-CG and SCI, with 3.4% of the SCI members also belonging to the IEEE-CG. Detailed salary and income data are given in the report in the form of plots of annual salary vs. years since receiving B.S., annual salary vs. years in the electronic-data processing (EDP) field, and annual salary vs. age for various cross sections of the information-processing profession.

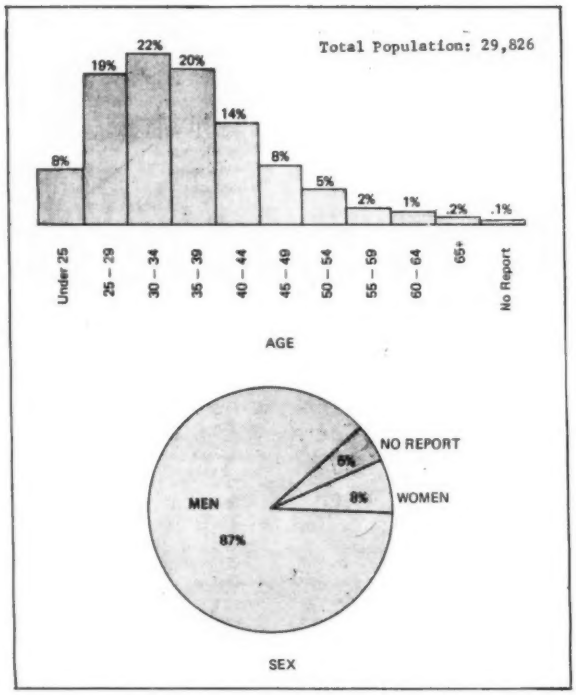


Figure 1. Personal data, age & sex (AFIPS Chart #1).

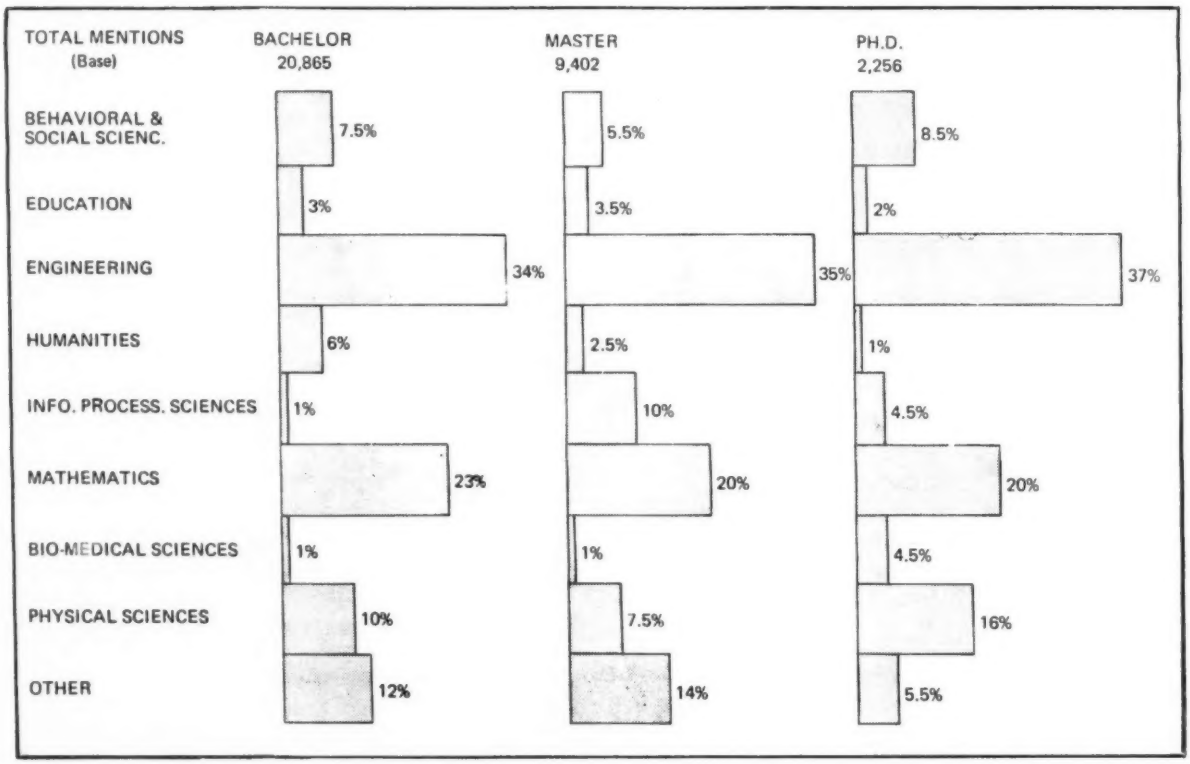


Figure 2. Education, distribution of disciplines, level of highest degree (AFIPS Chart #3).

Since the questionnaires were distributed by the societies to their memberships, and anonymity of the respondents was maintained, each society asked that individuals with more than one affiliation return only one questionnaire. It is believed that this request was complied with. The AFIPS survey is not considered representative of the large number of workers holding jobs as keypunch,

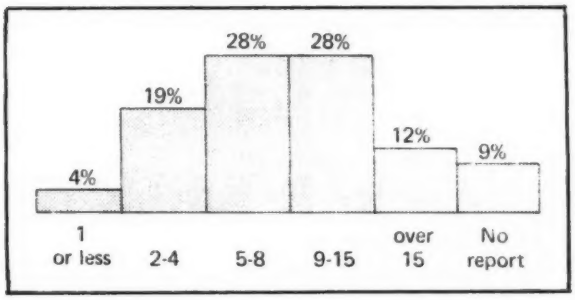


Figure 3. Employment, years of experience in the information-processing field (AFIPS Chart #4).

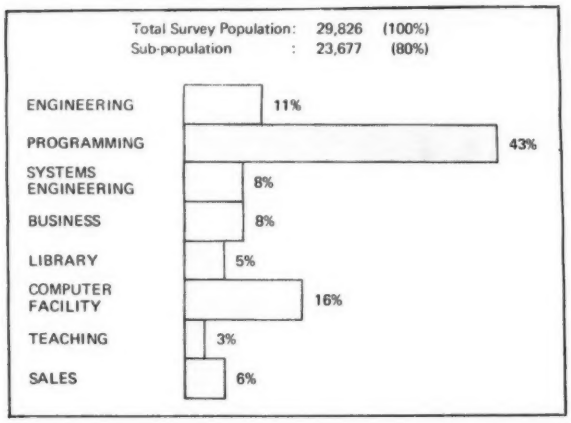


Figure 4. Employment, occupational specialties of builders of computer and data-processing tools (AFIPS Chart #6).

tape, and tabulating-equipment operators, or of other support personnel employed in computer and data-processing facilities, or of manufacturing and production technicians.

Responses from the survey suggest that it may be desirable for future questionnaires to be separated into two parts—one part that would be common for all societies, and a second part that would be tailored to the specific professional interests of particular groups. The AFIPS questionnaire did not, for example, subdivide categories of industries other than those directly associated with information processing. Some occupational specialties, though "esoteric" to some groups, were not sufficiently detailed for others. Qualifications for membership vary among the societies, and may affect trend analyses of the data.

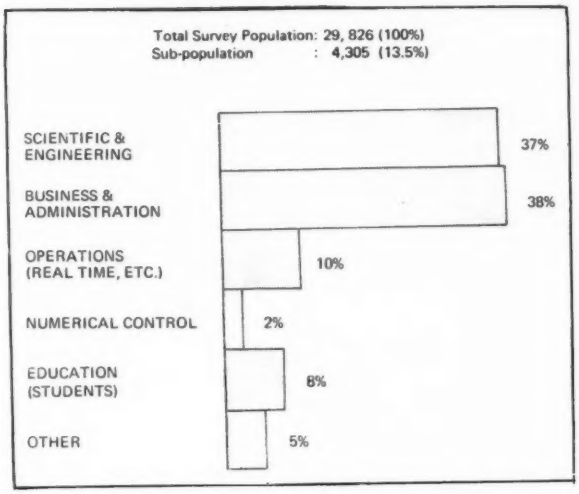


Figure 5. Employment, areas of application of users (AFIPS Chart #7).

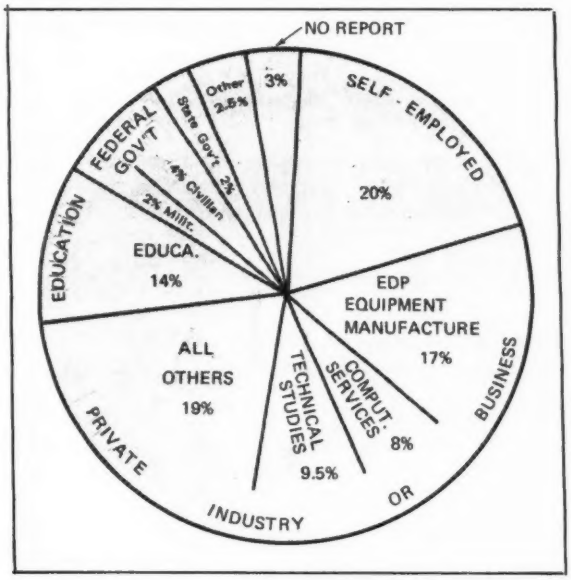


Figure 6. Employment, type of employer (AFIPS Chart #8).

This survey fills part of the gap in our knowledge about the characteristics of people presently engaged in information processing. It does not, however, include a number of professional society memberships or white- and blue-collar personnel. No analyses have been made of the data, although comments from respondents and the compilation effort have identified certain items that will require modification and elaboration for further study. The information-processing field has been and continues to be a rapidly changing one. It is, in part, a self-organizing field that is profoundly influenced by the new discoveries and

developments of its members. The growing requirements of commerce, industry, Government, and education for information processing and information-processing personnel suggest the need for comprehensive information about the people who are expected to build and man the information-processing systems, as well as about the hardware and software components of the systems. The AFIPS study is thus worthwhile not only in itself, but also for its significant contribution to a needed data base.

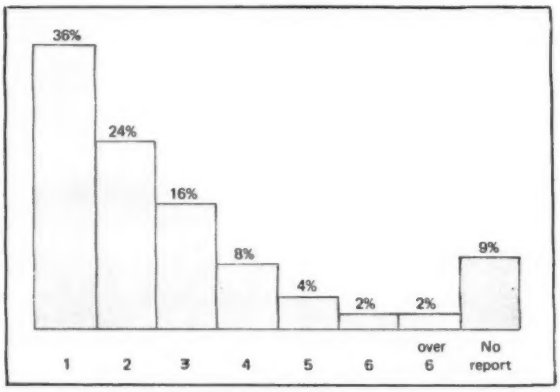


Figure 7. Employment, number of employers worked for since entering information-processing field (AFIPS Chart #11(B)).

Characteristic	1960 PGEC	1968 Members with Engin. Degrees	1968 Entire Population
AGE			
Median	33-36 years		34 years
EDUCATION			
(Highest Degree)			
None & Assoc. Arts	6%		31.5%
B.S.	51%	53%	37%
M.S.	34%	38%	24%
Ph.D.	9%	11%	7.5%
EMPLOYMENT			
Experience (Median)	8-9 years		8 years
Nature of Employer			
Self-Emp. & Private Ind.	86%		74%
Government	6%		8%
Education	7%		14%
Responsibility			
Supervisors	59%		60%
Non-Supervisors	41%		40%
Occupational Specialty			
	Engineering 58%	Engineering 34%	
		Systems Eng. 18%	
	Programming 4%	Programming 32%	
	Research 15%		
	Education 3%	Teaching 2%	
	Sales 2%	Sales 5%	
	Administr. 10%		
	Production 1%		
	Other 4%	Other 8%	

Figure 8. Comparison of some findings of the 1960 PGEC and 1968 information-processing personnel surveys (AFIPS Table #6).

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a new approach to monitoring nervous-system functional state and performance

DR. H. J. SANDER, Directorate of Life Sciences, AFOSR

The psychophysiological measurement of changes in the autonomic nervous system has often been considered as a method for monitoring the functional state and performance reliability of pilots of military and commercial aircraft. However, efforts to use measures such as heart rate, skin resistance, or blood pressure as indicators of alertness or emotional stress have been disappointing. One of the problems which has contributed to this lack of success has been the variability of these autonomic responses from one individual to another, or within one individual from time to time. This is most apparent in a typical psychophysiological monitoring procedure which involves the measurement of one or more variables of differences of response between rest and after stimulation. Many studies have shown that an increased heart rate, for example, cannot be assumed to accompany a general state of arousal or stress. Some subjects do not change in response to a stimulus; others show a decreased rate; and still others show an increase on one occasion and a decrease on another.

Dr. George E. Ruff of the Experimental Psychiatry Laboratory at the Pennsylvania Hospital, Philadelphia, under AFOSR support, has developed a new method of dealing with this problem. This is to focus on the baseline pattern of the variables for each individual subject. The baseline pattern of each variable is the recorded initial value obtained during the resting period. Fluctuations from the established baseline pattern, after stimulation, become more reliable indicators of the actual emotional state and performance reliability of the subject than current measures. The trick is to establish these baseline patterns for an individual.

Because of their low rate of change, it is only when recordings are made slowly that the amount of information conveyed by baseline patterns is fully appreciated It has been found, for example, that if *skin resistance* is recorded continuously at speeds of five centimeters per hour, patterns become apparent which are not seen on conventional tracings. These patterns are a relatively *stable characteristic* of an individual, although they change under different experimental conditions. They may be compared to an identifying signature which becomes shaky and unrecognizable under stress.

Shifts from the baseline pattern of an individual may be induced by internal conditions and by external stimulation. In addition, most people show spontaneous, cyclical or wave-like shifts within the baseline pattern which must also be taken into consideration.

Analysis of both induced and spontaneous variations from the baseline pattern is a method for detecting changes in the individual's performance condition. This involves identifying the patterns of baseline variation which are characteristic, on the one hand, of alert, efficient functioning for an individual and, on the other, of fatigue or stress.

About 100 subjects were tested by the investigator through the use of this approach. Complete data were obtained on half of them for a 2-hour run on each variable. Results of the study, to date, demonstrate that different activity levels of subjects are accompanied by changes from their baseline patterns on each variable. These changes are more consistent and meaningful than the "stimulus-response" differences shown in typical recordings. In the latter, detailed, "second-to-second" type of recording, the level of activity at the time of measurement is determined by multiple influences unknown to the observer. For example, the immediate heart rate response to stimulus may depend upon the pre-stimulus rate, the nature of the stimulus, whether it occurred during inspiration or expiration, etc. On the other hand, the baseline pattern is an overall product of many factors, and serves as a much more useful index of the state of the individual as a whole.

It is anticipated that further studies will establish more clearly the use of psychophysiological baseline patterns in the individual for use in monitoring alertness, reactions to stress, and other conditions necessary to man-machine performance activities.

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EUNICE C. CRONIN,
Analysis and Simulation Branch,
AFCRL Computation Center

Precise Long-Range Forecast of Satellite Decay

On January 24, 1969 AFCRL predicted that, on March 9, 1969, its ATCOS (Atmospheric Composition SAtellite) II satellite, in orbit at that time for 13 months, would reenter the earth's atmosphere. The actual hour of reentry was continually refined as new data came in. The final prediction, made on March 4, was within two hours of the actual decay time on March 9. This is the most precise long-range forecast of a satellite reentry made to date.

These predictions were made by using a system developed under contract (with AFCRL) by TRW Systems, Inc. The TRW system is one which rapidly integrates all factors influencing the satellite's trajectory—drag, lunar-solar gravitational attractions, earth oblateness, and terms from the geopotential which cause resonance.

The ATCOS II was designed, constructed, and instrumented by AFCRL scientists. It was launched on December 4, 1967, with a projected 256-day lifetime. But its actual useful lifetime was almost double this estimate. It continued to send data until it entered the atmosphere over Japan on March 9 after 7,203 revolutions.

Of the three density gauges on board at the time of launch from the Western Test Range, only one functioned; but this one continued to provide data without flaw throughout ATCOS II's lifetime. Of the two mass spectrometers carried, one functioned without interruption for the entire period. The second spectrometer became erratic in June 1968, stopped functioning for six months, and then regenerated itself to optimum performance until the end. A standing impedance probe was also aboard.

Miss Eunice C. Cronin is Chief of the Analysis and Simulation Branch, AFCRL Computation Center, which provides support to the AFCRL scientific research projects in mathematical/numerical analysis, the development of non-numeric systems, project satellite data reduction, orbital determination and operations, and analog/hybrid analysis.

In 1950, Miss Cronin received her B.A. in Mathematics and Physics from Trinity College, Washington, D.C., and is now working on her M.S. at Northeastern University. From 1952-1960, as an engineer for the U.S. Corps of Army Engineers, she made analytical studies of flood-control dams, multipurpose hydropower projects, and the applicability of electronic data processing to engineering problems.

Miss Cronin is a member of the Society for Industrial and Applied Mathematics, Simulation Councils, Inc., Association for Computing Machinery, and Society of Women Engineers. She is also the author of two publications.

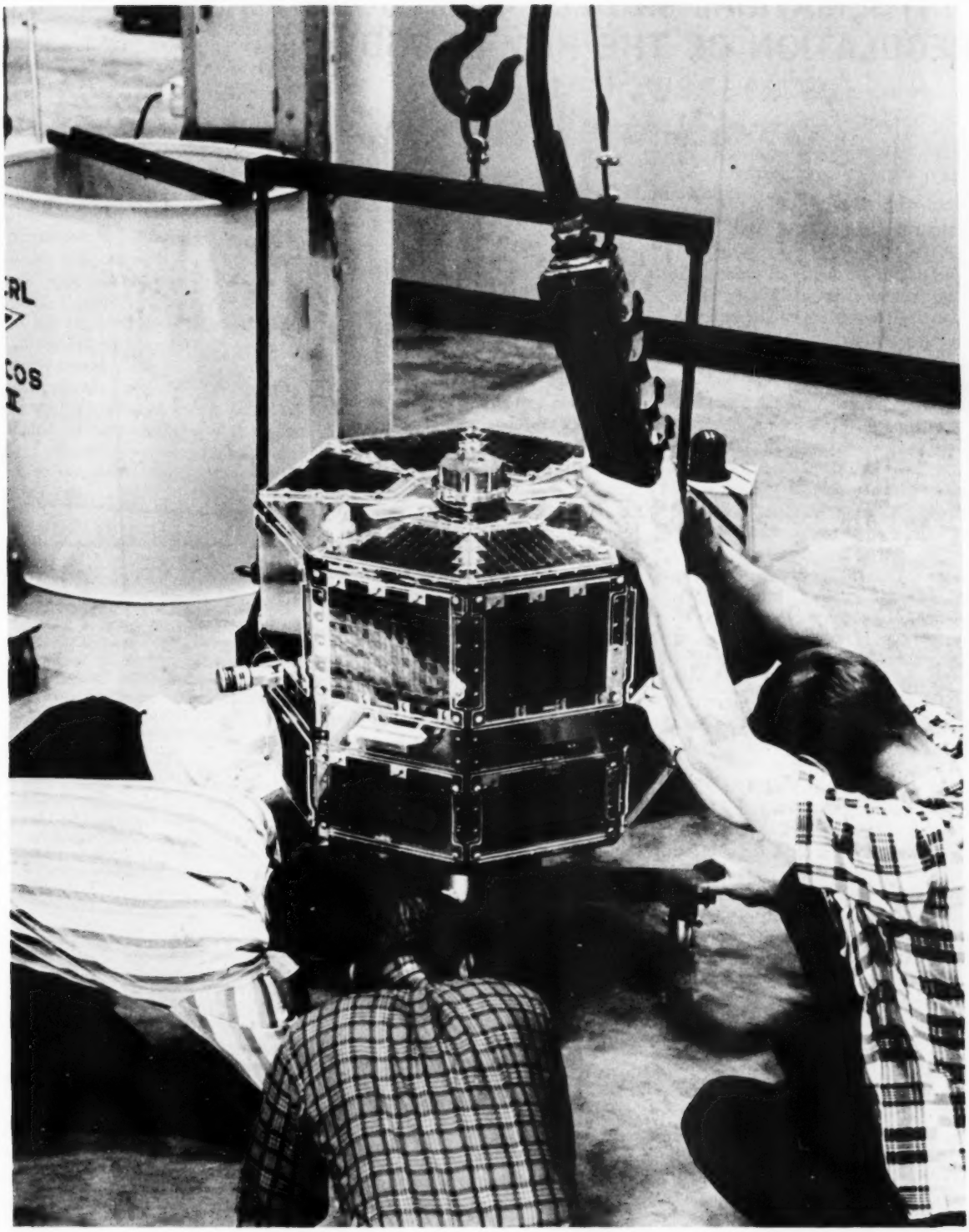

Figure 1. The Atcos II satellite immediately prior to its shipment to the West Coast for launch.

MATHEMATICAL MODEL FOR BLOOD-SUGAR REGULATION OF THE HUMAN BODY

DR. LYNN E. WOLAVER,
Applied Mathematics
Research Laboratory, ARL

Despite the fact that food intake in the human is an intermittent affair, occurring at arbitrarily fixed intervals, the sugar (glucose) concentration in the blood plasma is usually maintained at a nearly constant level. Its regulation represents an intricate control problem in which the liver, as the prime mover, is regulated principally by the blood-sugar level itself, with fine control being effected by the endocrine (pancreatic, adrenal, etc.) and the nervous systems.

In attempting to formulate a mathematical model of such a system, one is confronted with the eternal problem of choosing a model either so oversimplified (to make it mathematically feasible) that it is physically or realistically no longer interesting, or so realistic that it is mathematically intractable or perhaps even incompletely described. The advantages of linearization are many and, where adequate, such models are preferred; but no mathematical model, however simple or sophisticated, is of any value if it does not make physical sense—or, in this case, if it is not good physiology. Thus, the selection of a particular nonlinear model was guided by the criterion that the study of this model could in some way advance us toward a physical understanding of the real physiological problem.

From the physiology of each hormone and each human organ which contributes to carbohydrate metabolism, the author has developed a nonlinear mathematical model. Quantitative experimental data provided the functional relationships and many of the parameters of this model. For example, one can determine the rate of glucose loss from the kidneys as a function of the glucose concentration itself. However, not all of the para-

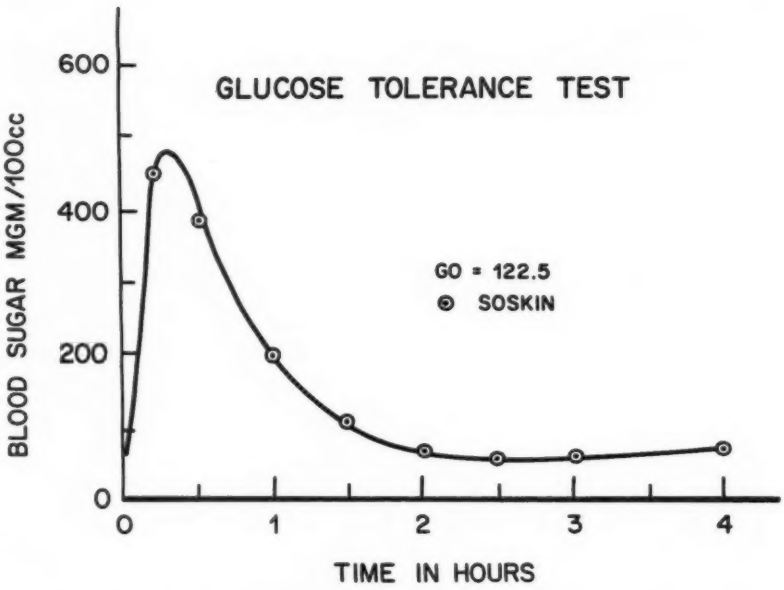

Figure 1. Model response curves: blood-sugar concentration as a function of time for intravenous glucose tolerance test.

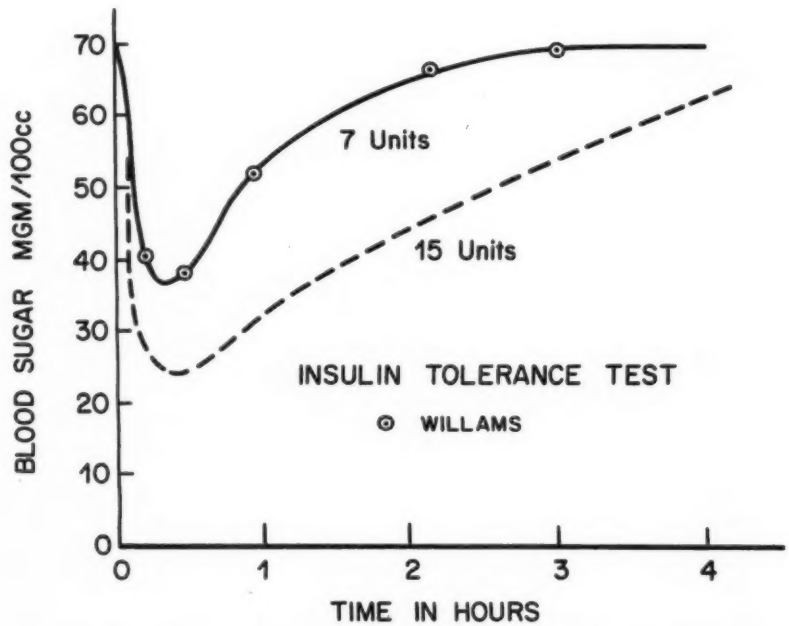

Figure 2. Model response curves: blood-sugar concentration as a function of time for insulin tolerance test.

metric values were known *a priori*. To determine these, the mathematical model was simulated on a computer and the unknown parameters chosen to give the desired dynamical response. Thus, the simulated model was made to conform to the actual autoregulatory system.

ARL's model covers the time span from a few seconds to about four hours following the normal glucose tolerance tests. A comparison of the model response with some actual human responses is shown in Figures 1 and 2. Current research is being conducted to formulate the functional form of the output of insulin from the pancreas in response to changing blood sugar and hormone levels. In addition, the mathematical model is being extended by incorporating the longer-term effects due to the contributions of fat and protein metabolism (glyconeogenesis).

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Dr. Lynn E. Wolaver has been Director of the Applied Mathematics Research Laboratory, ARL, since June 1967. He is also Professor of Mechanics at the Air Force Institute of Technology, and a lecturer in mathematics at Wright State University. His current research is in the areas of celestial mechanics, and in modeling and controlling nonlinear systems.

Dr. Wolaver received his B.S. in 1949 and his M.S. in 1950, both from the University of Illinois. In 1964, he was awarded his Ph.D. in Information and Control Engineering by the University of Michigan. He is the author of over 40 papers in the fields of navigation, astrodynamics, and nonlinear systems analysis. He is listed in *American Men of Science, Who's Who, Leaders in American Science, Dictionary of International Biography*, and the *World Space Directory*.

Vapor Pressure of Rare-Earth Elements

CAPT JAMES M. McCORMACK and LT COL RICHARD K. SAXER, FJSRL

Though the metals are not rare, the rare earths exhibits several noteworthy properties. As a class, the metals tend to be pyrophoric, form extremely stable oxides, and possess high thermal neutron absorption cross sections. In the past, rare earths have been used as alloy additions to modify the grain structure of cast metals, and in nuclear-engineering applications as reactor controls. More recently, a rare-earth alloy (samarium-cobalt) has exhibited outstanding performance as a permanent magnet material. Small additions of rare earths to Ni-base alloys have improved the high-temperature-oxidation resistance of these materials. This present research was begun as an attempt to broaden the base of thermodynamic data required for the further understanding and development of high-temperature-resistant alloys.

The vapor pressures of rare-earth metals are currently being investigated in a cooperative effort between the FJSRL and the USAFA Department of Engineering Mechanics. Measurements are made using the Knudsen effusion technique. Vapor pressures are determined from the flow rate of metal escaping into a vacuum through a small orifice in an enclosed cell. In practice, a weight loss, W, is measured after a specimen is heated for a time interval, t, at constant temperature, T(1). Vapor pressures are calculated from the relationship

$$P = \frac{W}{At}\, 2.258 \times 10^{-2} \sqrt{\frac{T}{M}}$$

based upon statistical thermodynamics. P is the vapor pressure in atmospheres, A is the orifice area, and M is the molecular weight of the effusing specie. For metals, the effusing species are monatomic.

Initial investigations were made on 99.5-percent pure erbium and dysprosium. Weight losses were measures at a minimum of 10 different temperatures. Vapor pressures were then calculated using a digital-computer program which accounted for weight losses during specimen heating and cooling. Least-square treatment of the data to a curve fit derived from the Clausius-Clapeyron relation yielded the following relations for the solid phase.

$$\ln P_{\text{mm Hg}} = \frac{-37060}{T} + 19.65 \quad \text{(erbium, 1352-1587° k)}$$

$$\ln P_{\text{mm Hg}} = \frac{-35620}{T} + 20.93 \quad \text{(dysprosium, 1239-1534° k)}$$

Results showed that the vapor pressure of erbium is nearly identical to that of copper. Dysprosium has a vapor pressure about an order of magnitude greater. The results agree with the previous estimates. (2)

Other significant results of the study showed that erbium and dysprosium vapor tend to react with Al_2O_3. Rare-earth oxides of the type M_2O_3 were formed.

Future investigation will be devoted to vapor-pressure measurements of high-purity holmium, ytterbium, and samarium.

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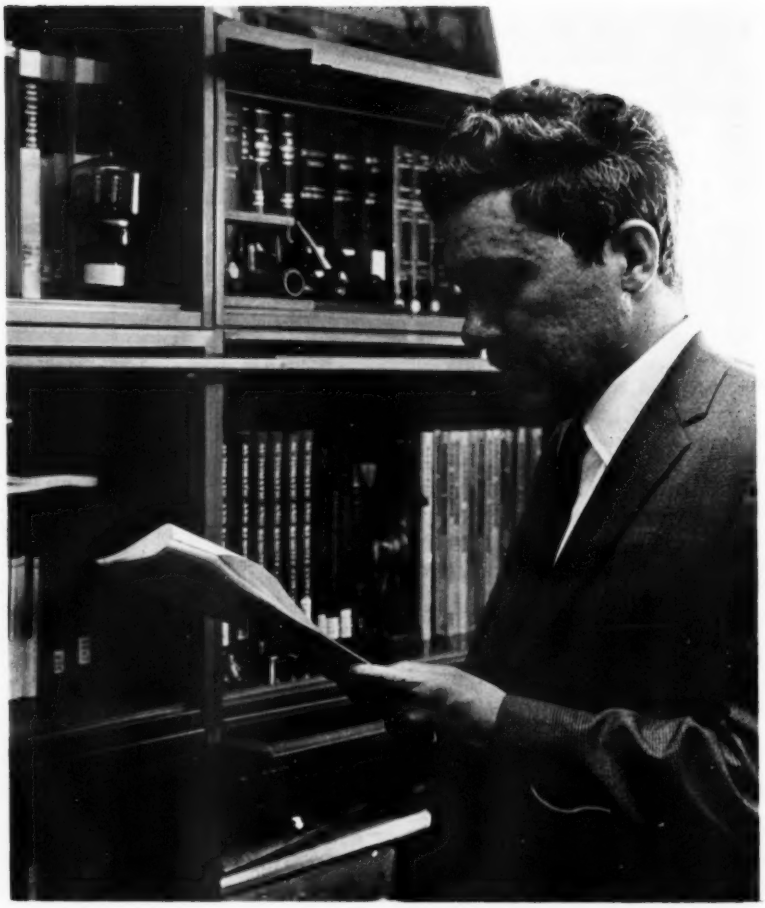
sleep and computer programming

DATA SCIENCES LABORATORY, AFCRL



Dr. Edmond Dewan, Research Physicist in the Biophysics Branch of the Data Sciences Laboratory, AFCRL, is currently engaged in work on the theoretical and experimental aspects of biological oscillations.

In 1953, Dr. Dewan received his B.S. in Physics, magna cum laude, from Duke University, and in 1957 earned his Ph.D. in Theoretical Physics from Yale University. His early experience included one year in the Psychiatric Research Laboratories of Massachusetts General Hospital, and three years in the Departments of Physics and Biology at Brandeis University. He is a member of Phi Beta Kappa, Sigma Pi Sigma, Pi Mu Epsilon, Sigma Xi, and several professional societies.

During our waking hours a continuous torrent of data reaches the brain. We read, we observe, we listen, we touch, we taste, and we monitor our motor tasks. What action we take or do not take with respect to a particular piece of newly acquired data is modulated by a set of instructions pre-established in the brain. This set of instructions, in computer terms, is a program. The program is the abstracted essence of a lifetime of experiences, plus instinctive drives and needs.

But while the program predisposes us toward a given behavior in response to each bit of new data, the new data feeds back to modify the program. Thus, we learn. Most of the daily accrual of data is "junk information" which must be sorted out and cleared from the memory. The rest must be ordered and assigned priorities based on potential usefulness. This process constitutes a kind of reprogramming. All of this takes place while the brain is "off line" which, again in computer terms, is a period during which the computer is not receiving and processing new data. In other words, the sorting-out process takes place during sleep.

The foregoing model was first suggested in 1965 by C. Evans and T. Newman of the National Physical Laboratory, Teddington, England. Since then, others, including Dr. Edmond Dewan of AFCRL, have independently developed similar models. Dr. Dewan has greatly extended and refined the model, and has weighed its validity against a range of observed physiological and psychological conditions. His extended model can be applied to studies of the effects of drugs, learning processes, hypnosis, sleep deprivation, brain lesions, psychosis, and many others. One important social implication, for example, stems from the fact that the programming of the brain is most pronounced during the prenatal and immediately postnatal periods of a person's life.

According to Dewan, programming and reprogramming occur only during a particular phase of sleep known as "REM" sleep. The REM acronym derived from the "rapid eye movement" characteristic of this phase of sleep. In an adult, REM sleep takes place during about 21 percent of his sleeping hours. Over the past decade, investigators have made scores of studies of REM sleep. A basic finding

arising from these studies is the fact that a person, if deliberately deprived of REM sleep for periods of more than two or three days, will undergo behavioral changes often indistinguishable from psychosis–distorted reality, hallucination, limited attention span, and so on.

This psychotic-like condition, to return to the computer analogy, is the product of an overloaded memory bank. The brain has had no opportunity to clear from memory the information and programming subroutines that are no longer useful, or to rearrange program elements in a more effective hierarchical fashion. Only when the accumulated backlog of data from the previous day has been reconsolidated is the set of instructions sufficiently uncluttered and internally consistent to cope efficiently with the new data inputs.

With this model, which Dr. Dewan calls the "Programming (P) Hypothesis for REM Sleep," many of the results obtained by those investigating REM sleep can be explained. The model serves as a basis for making a range of predictions–many already borne out in the results of REM sleep investigations, others still speculative. A most obvious prediction, for example, is that a person deprived of REM sleep for a period of time would experience a rebound, or an abnormal amount of REM sleep when no longer deprived. One would also expect that intense mental activity and stimulation during the day would result in increased REM sleep, while isolation or tranquilizing drugs would result in decreased REM sleep. These predictions are supported by test results.

If programming (the formulation of a basic set of instructions) and reprogramming (modifications of this program) take place only during REM sleep, it may prove instructive to look at REM sleep as a function of age. According to the model, a decrease in REM sleep with age is predictable. The reasoning here is that fewer modifications to the programs should occur with age because the person's basic goals, motor skills, drives, and interests (the products of a program) become reinforced, habitual, and less subject to daily modification. REM sleep begins before birth and, during the first year, about 60 to 70 percent of the child's sleeping hours are spent in REM sleep. The amount of REM sleep decreases until adolescence when it levels off at about 21 percent in the adult. At birth and in the early years, when the brain establishes the initial functional pathways that will endure a lifetime, we would expect to find a high percentage of REM sleep. It should remain high during adolescence when the basic program is still incomplete and subject to trial and error, with elements subject to drastic revision. With physiological maturity, however, the basic program is established, but still subject to daily reprogramming.

No stored set of procedures is invulnerable to the daily loss by the brain of about 10,000 neurons. To counter this erosion, programming instructions, even those enjoying the most entrenched and preferred positions in the hierarchically arranged program, must be continuously relocated in other parts of the brain. This relocation would occur during REM sleep.

The daily neuron loss may be considered as so many small lesions in the brain. What happens to the REM sleep requirements after lesions are made during a brain operation? Tests show a marked increase in REM sleep, which Dr. Dewan interprets as the process of relocating programming instructions. Similarly, REM sleep increases when fundamental patterns of behavior of a reflex nature are altered. In test subjects wearing special glasses which reverse left-right vision, REM sleep increased sharply–a situation that can be viewed as the need for the brain to quickly reprogram a long list of instructions relating to the processing of visual data.

In several papers over the past two years, Dr. Dewan has suggested a range of possible experiments to test the validity of his P-hypothesis. He also discusses certain implications of the model, one of which concerns hypnosis. It is interesting to speculate that, through the trance of hypnosis, the brain is taken "off line," permitting during this brief suspended interval the direct programming of the brain in the absence of REM sleep. On awakening, the subject simply processes all incoming data in accordance with instructions of the hypnotically inserted program.

How closely does the brain's spontaneous self-programming correspond to the known programming operations of computers? No one can say. But looking at the functions that the brain obviously performs in relation to known computer operations, many striking similarities are apparent. The computer in this sense can serve as a model–just as the Bohr atom is a kind of metaphoric model–which may prove extremely useful in our understanding of mental processes.

The Relevance of Basic Polymer Research to the Air Force

DR. WILLIAM L. RUIGH, Directorate of Chemical Sciences, AFOSR

The study of molecular configuration is the core of the present limited AFOSR polymer program. It is appropriate to provide an historical review of this program, particularly in view of recent spectacular British developments in high-strength graphite fibers whose structural properties depend upon the molecular configuration of the starting polymer which is subsequently graphitized by heat.

The annual AFOSR *Chemistry Program Review* for FY65 included a review of the Polymer Program of the AFOSR Directorate of Chemical Sciences by Drs. Amos G. Horney and

Anthony J. Matuszko. (Dr. Horney is Director of Chemical Sciences, AFOSR, and Dr. Matuszko is a scientist in his Directorate.) The article described the research of Dr. Paul J. Flory, Professor of Chemistry at Stanford University, on the spatial configuration of chain molecules, of Dr. Peter Debye on the molecular interactions of polymers as measured by visible light and X-ray scattering, and of Dr. Richard Stein on crystal orientation and structure and change in polymers as induced by stress observed by the "dynamic birefringence" of the polymer film.

For FY 1966 Dr. Matuszko reviewed the work of Dr. D. J. Cram on the asymmetric induction of stereospecific polymers, and also of Dr. Frank Mayo on mild oxidations common to hydrocarbon chain polymers. A grant to Dr. A. V. Tobolsky, which expired in FY 1966, though not reviewed, resulted in a number of papers on the mechanism of both radical and ionic polymerization, a general treatment of equilibrium copolymerization, and the structure and transitions of helical macromolecules in the solid state.

The main emphasis of this limited AFOSR program in macromolecules has been on the physical chemistry of polymers, with some additional work on the more theoretical aspects of certain reaction mechanisms and catalysts useful in polymer synthesis. Only one effort has been directed at the synthesis of a specific polymer system since, historically, the Polymer Branch of the Air Force Materials Laboratory at Wright-Patterson Air Force Base, Ohio, has had primary responsibility for an in-house and contractual program aimed at the synthesis of new and improved organic and inorganic polymers designed to meet the extreme requirements of the Air Force. With pressing day-to-day demands for these new materials, less emphasis has been directed at long-term fundamental efforts, particularly in the area of the physical chemistry of polymers.

AFOSR's Directorate of Chemical Sciences has from the beginning tried to fulfill this need of the Air Force for long-term basic research in the stereochemistry and physical chemistry of macromolecules. Fortunately, the world's foremost authority in this area, Dr. Paul J. Flory, then at Cornell University, was selected by Dr. Horney to be the first Chairman of the AFOSR Chemistry Review Panel. Remaining with the Panel during its first seven years, Dr. Flory helped build up a strong basic program.

The rising costs of research and the budgetary plateau reached by AFOSR's Directorate of Chemical Sciences have resulted in a substantial cutback in this limited program; since the FY 65 review, the only new effort added has been a grant in FY 68 to Dr. F. Karasz, formerly at General Electric and now at the University of Massachusetts, to continue his research on the calorimetry and thermodynamics of organic polymers.

The work of Dr. Karasz, plus the large project under Dr. Flory, now constitute the entire AFOSR program. However, Dr. Flory's work at Stanford University, funded by AFOSR for the first time in October 1961, has been outstanding and very productive. For example, during his latest grant period from February 1964 to October 1968, Dr. Flory's program resulted in 53 papers published in major journals. His work on the physical chemistry of polymers can be subdivided into two main areas: (1) the structure and stereochemical configurations of polymeric chains, and (2) the thermodynamic treatment of the equilibrium properties of solutions.

The practical importance of a basic theoretical knowledge of polymer configuration on the explanation and prediction of polymer properties is illustrated in the title of a lecture given by Dr. Flory at the Goodyear Medal Address in Cleveland in April 1968. The title was "Molecular Interpretation of Rubber Elasticity." Dr. Flory has just received the Peter Debye Award in Physical Chemistry, based on his well-known work on macromolecules.

Knowledge of the molecular configuration of polymers has led to one of the most spectacular achievements in the aviation industry in recent years: the development of a very-high-strength graphite fibre from the carbonization of certain specially configured organic polymers by the Royal Aircraft Establishment at Farnsworth, England, the Rolls Royce Company, and two other British companies.

At present, great secrecy surrounds the production processes for the "Hyfil" graphite fibres now being made by the three British companies for the preparation of composite materials. Probably the present most-favored starting polymer is a specially processed polyacrylonitrile. It is known that the molecular conformation of the original polymer has a great influence on the subsequent strength and properties of the final carbon fiber.

The Rolls Royce success with composite graphite fibre compressor blades has enabled the company to design jet engines such as the RB168 for vertical-take-off experimental planes, and the RB211 engine for the Lockheed L-1011 "Air Bus." An early problem with the composite blades was ingestion damage in tropical rainstorms. Rolls Royce, however, claims the present nickel-plated "Hyfil" compressor blade has overcome these difficulties and will resist the impact of a four-pound bird.

Although the present "Hyfil" costs are high, the British have a large program on the engineering and structural use of the carbon composites, from application in satellite materials to the fabrication of composite honeycomb air-wing panels. A series of articles in *Aviation Week* in October 1968 discussed these recent developments both here and in England.

Although the details still remain largely secret, it is certain that a basic knowledge of the molecular configuration of polymers and their modification by physical treatment have contributed greatly to this breakthrough in materials. Much of this basic knowledge of polymer structure and configuration is due to the universally acknowledged research contributions of Dr. Flory in this field.

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